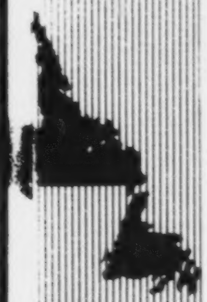

MINERAL DEVELOPMENT DIVISION
DEPARTMENT OF MINES AND ENERGY
GOVERNMENT OF NEWFOUNDLAND AND [illegible]

CURRENT RESEARCH

REPORT [illegible]

Compiled and Edited by
R.F. Blackwood, D.G. W[illegible]

St. John's Newfoundland
March 1986

86-04487/

Mineral Development Division
Department of Mines and Energy
Government of Newfoundland and Labrador

CURRENT RESEARCH

Report 86-1

Compiled and Edited by
R.F. Blackwood, D.G. Walsh and R.V. Gibbons

St. John's, Newfoundland
March, 1986

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PREFACE

This publication is the thirteenth in the Mineral Development Division's annual Current Research series.

The Division continued its ongoing program of geoscientific studies in 1985, supported and assisted by the Geological Survey of Canada under the Canada-Newfoundland Mineral Development Agreement, 1984-1989. This was the second year of the Agreement, and all projects planned were fully operational. New projects were added in regional mapping in Labrador, and in metallogeny of granitoid-related mineral deposits on the Island.

This year also saw the Division's first projects in geophysics, filling a long-standing gap in our program. Geophysics projects were led by our own geophysicist, who came on staff early in 1985, and by Dr. Hugh Miller of Memorial University, who is spending a sabbatical year with the Division. A wide range of geophysical studies were carried out in support of mapping, geochemical and mineral deposit projects.

The Geological Survey of Canada carried out a variety of projects in the Province under the Mineral Development Agreement. Full reports on these projects will appear in the GSC Current Research (GSC Paper 86-1). We thank the GSC for permission to include abstracts of these reports here.

B.A. Greene
Director
Mineral Development Division

Any reader who would like to write a rebuttal to, or discussion of, any report contained in this volume is invited to submit it to the editor by November 1, 1986, to be considered for inclusion in Report 87-1.

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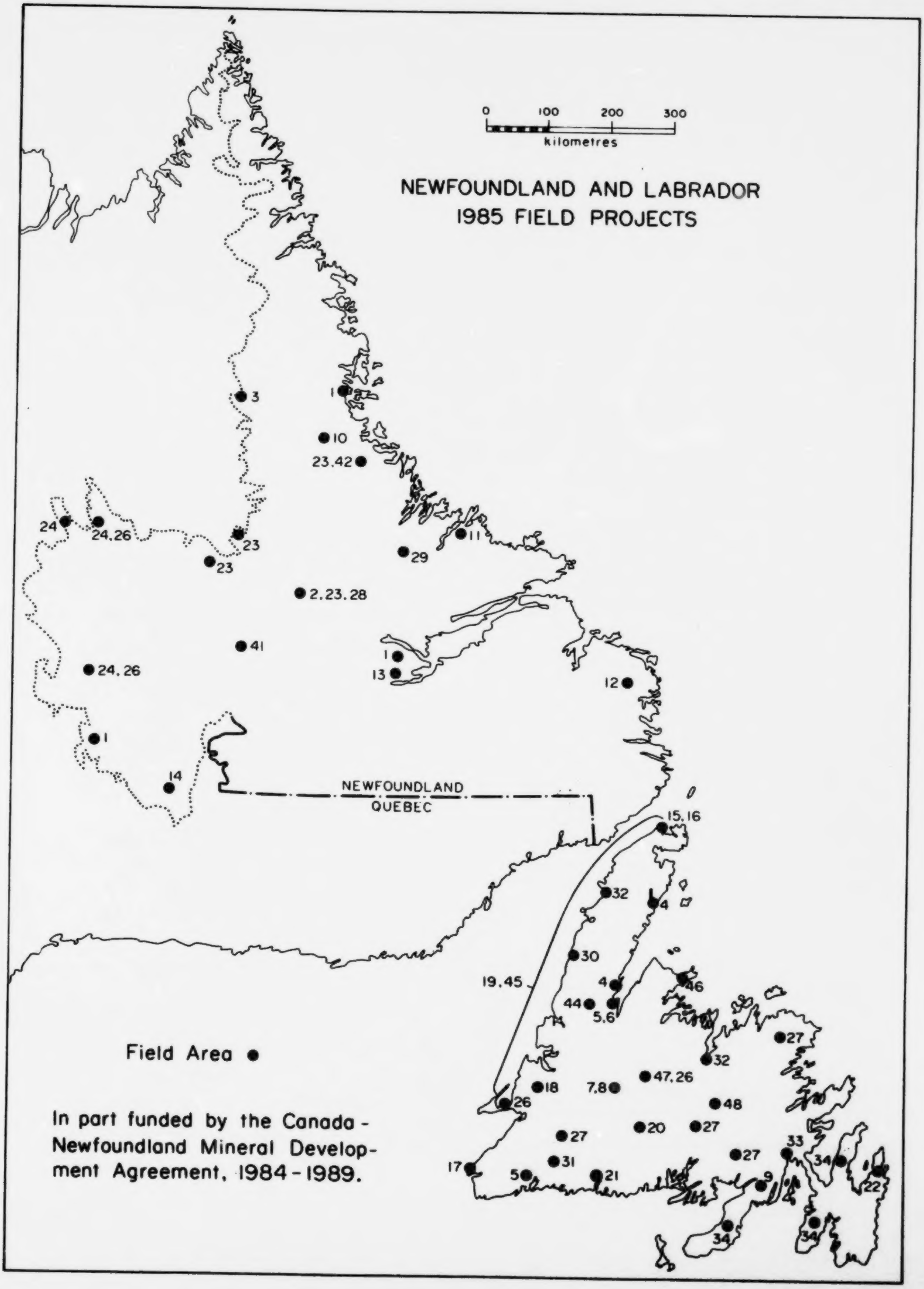

NEWFOUNDLAND AND LABRADOR
1985 FIELD PROJECTS

Field Area ●

In part funded by the Canada - Newfoundland Mineral Development Agreement, 1984 - 1989.

0
100
200
300
kilometres
NEWFOUNDLAND
QUEBEC
1
3
10
23,42
24
24,26
23
23
11
29
2,23,28
41
1
13
24,26
12
1
14
15,16
32
4
30
19,45
4
44
5,6
46
27
32
18
7,8
47,26
26
48
27
20
27
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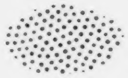
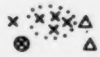
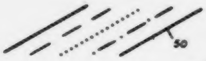
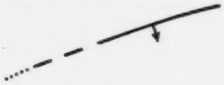
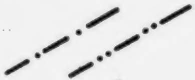
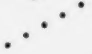
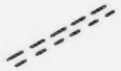
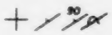
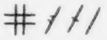
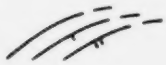
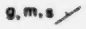
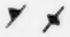
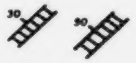
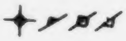
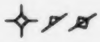
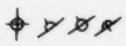
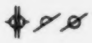
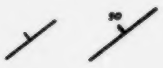
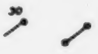
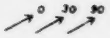
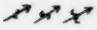
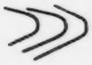
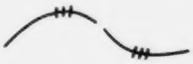
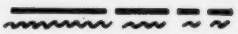
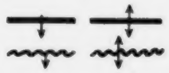
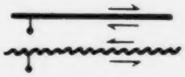
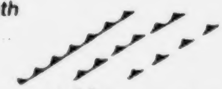
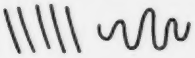
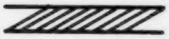
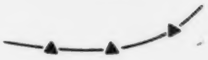
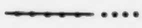
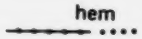
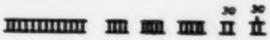
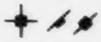
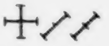
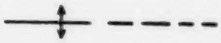
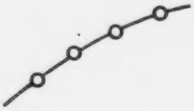
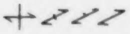
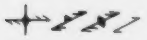
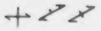
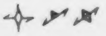
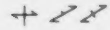
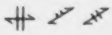
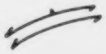
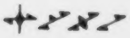
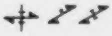
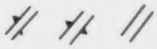
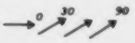
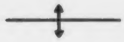
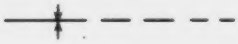
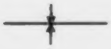
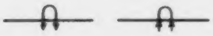
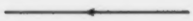
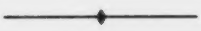
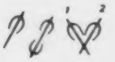
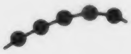
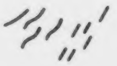
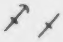
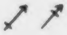
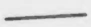
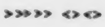
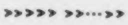
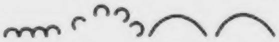
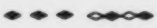
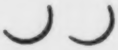
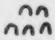
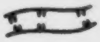
34

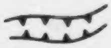
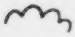
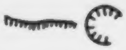
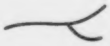
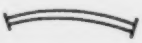
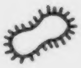
LIST OF SYMBOLS USED ON GEOLOGICAL MAPS AND FIGURES

Drift covered area	
Rock outcrop, area of outcrop, probable outcrop, float, frost-heaved rock	
Geological boundary (defined, approximate, assumed, gradational, dip indicated)	
Intrusive contact with younger unit indicated	
Unconformity (defined, assumed)	
Limit of geological mapping	
Limit of area surveyed with aircraft	
Bedding, tops known (horizontal, inclined, vertical, overturned)	
Bedding, tops unknown (horizontal, inclined, vertical, dip unknown)	
Bedding, general trend (dip unknown, top unknown; dip and top known; dip known, top unknown)	
Bedding, estimated dip (gentle, moderate, steep)	
Igneous flow banding (inclined, vertical)	
Igneous intrusive sheets (inclined, vertical)	
Primary igneous layering, tops known (horizontal, inclined, vertical, overturned)	
Primary igneous layering, tops unknown (horizontal, inclined, vertical)	
Strike and dip of pillows, tops known (horizontal, inclined, vertical, overturned)	
Strike and dip of pillows, tops unknown (horizontal, inclined, vertical)	
Primary igneous mineral lamination (inclined, vertical)	
Primary igneous mineral lineation (inclined, vertical)	

Age of lineation and of minor fold axes	
Lineation of unknown age	
L_1	
L_2	
Axes of minor folds (horizontal, inclined, vertical)	
Sense of vergence of minor structures (used with minor fold axes symbol or lineation S intersection symbol; read looking along the arrow)	
Structural trend (from aerial photographs)	
Lineament (from aerial photographs)	
Fault (defined, approximate, assumed)	
Fault (inclined, vertical)	
Fault (solid circle indicates downthrown side, arrows indicate relative movement)	
Thrust fault (teeth in direction of dip; defined, approximate, assumed) (teeth indicate upthrust side)	
Zone of numerous imbricate thrust faults	
Fault zone, shear zone (width indicated)	
Tectonic slide	
Vein fault (defined, assumed)	
Mineralized bed or seam (hematite)	
Dike, vein, or stockwork (defined, approximate, assumed; unit number and dip indicated)	
Joint (horizontal, inclined, vertical)	
Sheeted dikes (horizontal, inclined, vertical)	
Anticline (defined, approximate, assumed)	

Flow Contact	
Zone containing xenoliths	△
Zone of intrusive agmatite	▲
Roof pendant (unit number indicated; too small to map separately)	△
Zone containing autoliths	▽
Breccia of various origins	▼
Slaty cleavage (horizontal, inclined, vertical, dip unknown)	
Strain-slip cleavage (horizontal, inclined, vertical, dip unknown)	
Schistosity, cleavage, foliation; used where ages of foliation are indicated on the map (horizontal, inclined, vertical)	
Schistosity of unknown age	
S_1	
S_2	
Schistosity, gneissosity, cleavage, foliation, general trend	
Gneissic foliation (horizontal, inclined, vertical, dip unknown)	
Gneissic banding (horizontal, inclined, vertical)	
Axial plane of minor fold (inclined, vertical, dip unknown)	
Lineation (horizontal, inclined, inclined but plunge unknown, vertical)	
Type of lineation denoted by letter:	
Mineral lineation	M→
S intersections	S→
Microcrenulations	C→
Boudin axes	B→
Deformed clasts	D→
Igneous inclusions	I→
Rodding, mullion structure	R→
Metamorphic aggregates	A→
Deformed pillows	P→

Antiform	
Syncline (defined, approximate, assumed)	
Synform	
Anticline and syncline (overturned)	
Anticline or syncline (arrow indicates plunge)	
Antiform or synform	
Glacial striae (direction of ice movement known, unknown). Numbers indicate relative age, 1 being the oldest	
End moraine	
Minor moraines, rib moraines, washboard moraines, "annual" moraines, till ridges transverse to ice flow (irregular, straight)	
Drumlins, drumlinoid ridges (direction of ice movement known, unknown)	
Crag and tail hills and ramps	
Glacial linear feature	
Pingo or palsen	
Esker (direction of flow known, unknown)	
Esker (continuous, discontinuous)	
Raised beaches	
Limit of marine or lacustrine submergence (well marked, assumed)	
Dunes	
Area of sand dunes	
Buried valley	

Abandoned river channel, spillway, ice-marginal channels, rill patterns, etc.	
Landslide scar	
Escarpment and cirques	
Fossil locality	Ⓕ
Locality where age has been determined, in millions of years	Ⓐ 180
Ice divide	— — —
Land system boundary	
Location of measured section	
Gravel pit or quarry (active, abandoned)	× $\underline{\times}$
Borrow pit (active, abandoned)	$\overline{\times}$ $\overline{\underline{\times}}$
Rock dump or tailings	
Rock quarry (active, abandoned)	$\underline{⚒}$
Mine (lead, zinc)	⚒ Pb, Zn
Mine (lead, zine; abandoned)	$\underline{⚒}$ Pb, Zn
Mineral prospect; mineral occurrence (manganese)	×9 × Mn
Placer deposit (gold)	× Au
Show of oil and gas (abandoned)	✱
Show of gas(abandoned)	☼
Gas producer	○
Oil producer	✹
Oil and gas producer	●

Location of drilling	○
Dry (abandoned)	⌖
Water source or disposal	⊸
Shearing and dip	⟋
Salt spring	ss○
Hot spring	hs○
Mineral isograd	-■-■-■-■-■-
Other alternatives when more than one	□ ○ ● △ ▲
Shaft, raise, winze	◪ ■ ◩
Shaft (abandoned)	◪
Trench	≍
Open cut; axial	∩
Adit or tunnel	≻— ≻=
Adit or tunnel (caved)	≻+ ≻≠
Borehole	●BH ●BH 3
Diamond drill hole	● DDH
(Surface projection of geology inferred)	—○
Sinkhole	○ SH
Gossan	G G G
Trace of coal seam	—— ——

Current Research (1986) Newfoundland Department of Mines and Energy, Mineral Development Division, Report 86-1, pages 1-8

INDUSTRIAL MINERALS IN LABRADOR

J.R. Meyer and P.L. Dean
Mineral Deposits Section

ABSTRACT

An assessment of industrial minerals in Labrador continued in 1985 with investigations into dolomitic marble, silica and alumina potential, and dimension stone. The best silica prospect in western Labrador contains greater than 99.5 percent SiO_2. Preliminary geochemical analyses indicate that the dolomitic marble meets the specifications for use in the making of self-fluxing 'dolomite-type' iron ore pellets.

Silica deposits were investigated in southeastern Labrador, 25 km southwest of Mary's Harbour. Large quartz-feldspar vein systems form two northeast-trending, undulating ridges that have up to 150 m in relief. Many features within these vein systems suggest the presence of fossil hydrothermal systems and selected samples are being tested for precious metals.

Anorthosite in the Goose Bay area was evaluated as a potential source of alumina, since grab samples collected in 1984 contain up to 27 percent Al_2O_3. Preliminary investigations of the Nain anorthosite indicate that it has excellent dimension stone potential. Its tidewater exposures of massive, coarsely crystalline, medium-gray anorthosite contain uniformly distributed, chatoyant labradorite crystals, and would make extremely attractive facing stone for buildings.

INTRODUCTION

This is the second year of a program investigating the industrial mineral potential of Labrador. It was initiated in 1984 in the Wabush/Labrador City area in an attempt to strengthen and diversify the area's economic base, which is almost entirely dependent on the iron ore industry. In 1985, a total of nine holes and 183 m of core were drilled in the vicinity of the two best marble prospects discovered in 1984. New surveys were initiated in southeastern Labrador and in the Goose Bay and Nain areas (Figure 1).

INDUSTRIAL MINERAL SURVEYS

Dolomitic Marble - Labrador West

An industrial mineral survey carried out in the Wabush/Labrador City area in 1984 established the presence of high quality silica reserves and very pure dolomitic-marble deposits. During the 1985 field season, a three-week drill program was carried out to continue the assessment of the dolomitic marble in two Exempt Mineral Land blocks, which were established as a result of the 1984 sampling program.

The dolomitic marble is being investigated primarily for its potential use in the iron ore industry. To cope with the regression of iron and steel over the last 10 years, there has been a significant effort by the industries to reduce the final cost of producing raw steel from iron ore. This has led to increased beneficiation of iron ore through finer grinding, more energy efficient pelletization techniques, and the development of stronger, more reducible pellets for blast furnaces. One such pellet which may maximize these new developments is the dolomite-pellet type (Ilmoni, 1985), in which a small percentage of dolomite is mixed in with the iron ore concentrate prior to balling of the pellets. The resulting self-fluxing pellets are presently used in Japanese and European blast furnaces, and with the ongoing development of these pellets their usage should become much more widespread in North America and elsewhere.

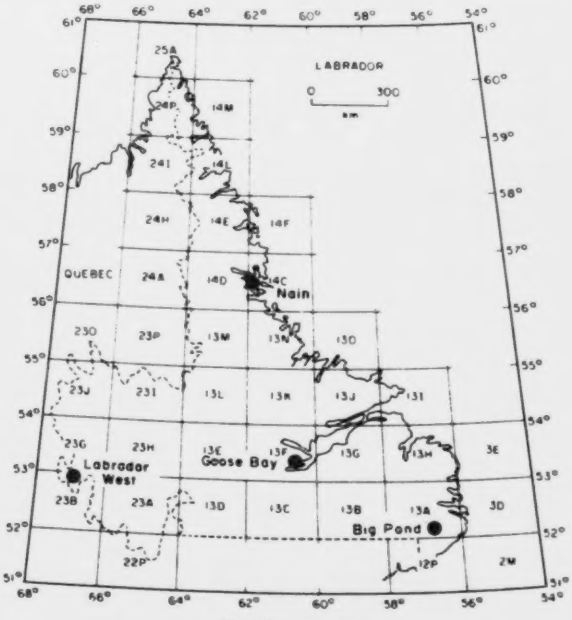


Figure 1: *Location map for 1985 industrial mineral projects in Labraodr.*

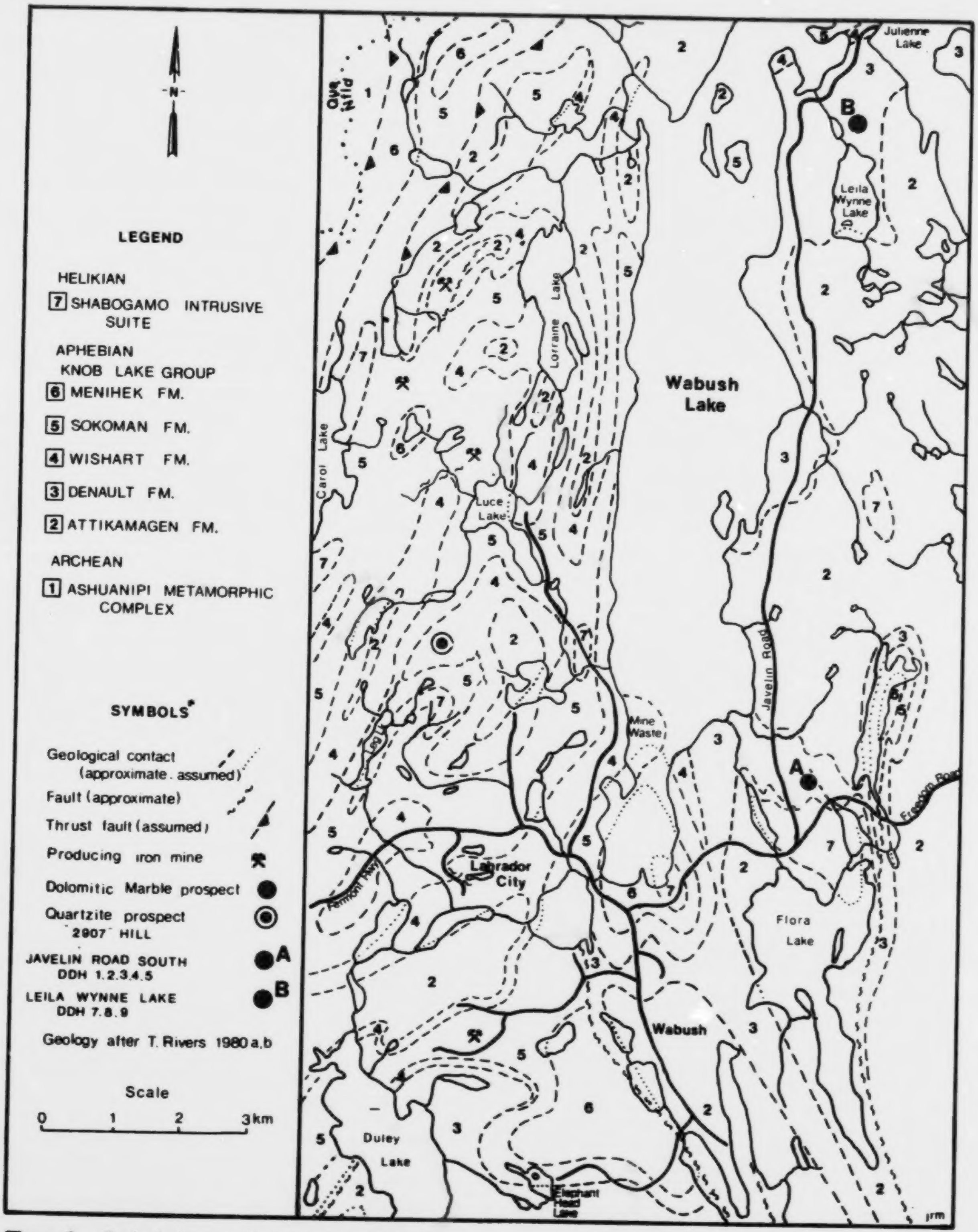

N
LEGEND
HELIKIAN
7 SHABOGAMO INTRUSIVE SUITE
APHEBIAN
KNOB LAKE GROUP
6 MENIHEK FM.
5 SOKOMAN FM.
4 WISHART FM.
3 DENAULT FM.
2 ATTIKAMAGEN FM.
ARCHEAN
1 ASHUANIPI METAMORPHIC COMPLEX
SYMBOLS*
Geological contact (approximate, assumed)
Fault (approximate)
Thrust fault (assumed)
Producing iron mine
Dolomitic Marble prospect
Quartzite prospect "2907" HILL
JAVELIN ROAD SOUTH DDH 1.2.3.4.5
A
LEILA WYNNE LAKE DDH 7.8.9
B
Geology after T. Rivers 1980 a,b
Scale
0
1
2
3km
Que. Nfld
Julienne Lake
Leila Wynne Lake
Lorraine Lake
Wabush Lake
Carol Lake
Luce Lake
Javelin Road
Mine Waste
Freedom Road
Labrador City
Flora Lake
Wabush
Duley Lake
Elephant Head Lake
jrm

Figure 2: *Geological map of Labrador City-Wabush area.*

It is very fortunate that the sedimentary sequence which hosts the iron formations in western Labrador also contains a dolomitic marble unit, the Denault Formation. In 1984, chip and channel samples were collected from the dolomitic marble, which is exposed to the south and east of Wabush Lake (Figure 2). Geochemical analyses of these samples indicate that two areas of exposure could meet the chemical specifications for self-fluxing pellets. To assess the two areas nine holes were drilled in 1985 using a portable 'Winkie' drill.

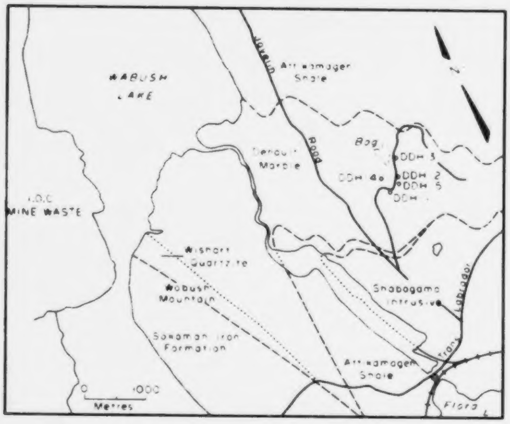


Figure 3: *Location of drillholes in Javelin Road South prospect.*

The first area drilled was the Javelin Road South prospect. It is located 7 km east of the Iron Ore Company of Canada's pellet plant and adjacent to a small dirt road that branches off the south end of the Javelin road (Figure 3). Five holes were drilled in this area and bedrock set-ups were used wherever possible, as 7 m of stoney till is maximum penetration for the Winkie drill (this was discovered in drillhole #4). This severely limited the drill program in the Javelin Road South prospect as there is very little outcrop there. The most favourable drill core in this prospect comes from drillhole #1, which contains 22 m of consistently clean, white, coarsely crystalline dolomitic marble. This reflects the excellent chip and channel sample results obtained from surface exposures at this locality in 1984. The small percentage of impurities observed in the drill core consist of: 1) light-brown to clear patches of tremolite up to 3 mm in diameter, 2) laminations of pale-green tremolite ranging from 1 to 4 mm in thickness, 3) rare quartz laminations and lenses 1 to 3 mm thick, and 4) very small amounts of finely disseminated pyrite and/or chalcopyrite. The sulfides are typically associated with the tremolite or quartz laminations. Preliminary geochemical analyses for the top of this hole are presented in Table 1. The drillhole intersects a 12 cm wide, greenish-gray band of gabbro at 11 m and it ends in similar rock at 21 m. These gabbro units are interpreted to be sills and/or veins of Shabogamo gabbro, which outcrops 1 km to the south. The dolomitic marble may continue below the gabbro.

Table 1. Preliminary geochemical analyses* from selected drill core intervals.

	Sample #	CaO	MgO	SiO_2	Al_2O_3	Fe_2O_3	P_2O_5	Sample Interval
DDH 1	5445061	29.6	21.7	0.95	0.18	0.13	0.03	1.68 m (5.5')
	5444062	28.8	20.3	4.19	0.11	0.17	0.04	0.46 m (1.5')
	5445063	29.4	21.0	2.54	0.05	0.20	0.02	1.52 m (5.0')
	5445064	29.5	21.1	1.82	0.06	0.16	0.02	1.52 m (5.0')
	5445065	28.1	20.2	6.39	0.62	0.19	0.04	1.52 m (5.0')
Average		29.13	20.9	2.96	0.22	0.17	0.03	
DDH 5	5445114	26.8	19.0	11.21	0.10	0.19	0.01	0.91 m (3.0')
	5445115	25.3	17.3	15.40	0.08	0.54	0.06	0.61 m (2.0')
	5445116	24.8	17.7	14.59	0.08	0.16	0.02	1.83 m (6.0')
	5445117	25.7	18.8	11.21	0.13	0.20	0.02	2.13 m (7.0')
	5445118	25.8	18.9	11.72	0.66	0.50	0.03	1.37 m (4.5')
Average		25.6	18.40	12.59	0.21	0.29	0.02	
DDH 7	5545133	28.5	20.4	5.77	0.11	0.23	0.03	1.83 m (6.0')
	5445134	30.0	21.2	3.64	0.11	0.24	0.03	1.49 m (4.9')
	5445135	30.1	21.0	3.31	0.11	0.29	0.06	2.29 m (7.5')
	5445136	29.6	21.3	3.00	0.11	0.37	0.06	2.29 m (7.5')
	5445137	24.9	17.4	18.17	1.34	0.40	0.22	3.05 m (10.0')
Average		28.2	20.0	7.95	0.46	0.32	0.10	
DDH 9	5445156	28.9	21.5	2.51	0.06	0.20	0.05	2.44 m (8.0')
	5445157	29.7	21.9	0.96	0.05	0.30	0.08	2.44 m (8.0')
	5445158	29.4	20.8	3.13	0.05	0.27	0.04	2.44 m (8.0')
	5445159	29.4	21.3	2.54	0.05	0.26	0.02	2.44 m (8.0')
	5445161	28.3	20.7	5.29	0.09	0.27	0.02	1.52 m (5.0')
Average		29.2	21.3	2.69	0.06	0.26	0.04	

* carried out by Iron Ore Company of Canada.

Three more holes, ranging from 25 to 37 m in depth, were drilled 150 to 400 m northeast of, and across the regional strike from drill hole #1 (Figure 3). They intersected light-gray to white, dolomitic marble that is generally banded and locally iron stained. Tremolite and quartz laminations, lenses, and patches are more abundant and thicker, averaging 3 to 8 percent over the total length of the holes. Geochemical analyses from the top of drillhole #5 (Table 1) confirm these field observations of the core. The only other encouraging drill intersections from this area are the bottom 7 m of drillhole #2 (between 30 and 37 m depth), and the top 7 m of drillhole #3. These intervals consist of white, coarsely crystalline, dolomitic marble with 1 to 4 mm patches of yellow to white tremolite.

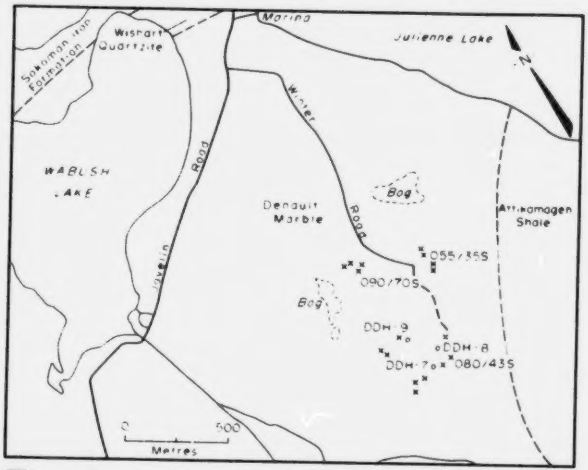


Figure 4: *Location of drillholes in Leila Wynne Lake Prospect.*

The second prospect drilled is located 1.5 km southeast of the north end of the Javelin road and 700 m north of Leila Wynne Lake (Figure 4). Access to the area is by foot or by helicopter, although there is a winter road that ends 750 m from this prospect. The exposures of dolomitic marble are much more extensive in this area and there is only a thin cover of overburden. Three holes were drilled to begin the assessment of this prospect, but there is a need for many more holes to prove its full potential. Drillhole #7, located at the site of a bulk sample collected in 1984, contains an average of nearly 10 percent quartz, tremolite and pyrite over the length of the hole (Table 1). However, 70 m to the northeast at drillhole #8, the marble is much cleaner, whiter, and more coarsely crystalline. This trend continues with drillhole #9, located 150 m northwest of drillhole #8; it intersects 25 m of extremely white dolomitic marble. The core from drillhole #9 contains rare, 1 to 3 mm wide, quartz laminations, light-brown patches of tremolite, 1 to 5 mm in diameter, and minor, widely spaced, faint-gray bands that indicate the presence of trace amounts of finely disseminated pyrite. The dolomitic marble in this hole equals the purity and consistency of the core from drillhole #1 of the Javelin Road South prospect (see Table 1), and there is much better potential for large reserves of high quality dolomitic marble in this area. Dolomitic marble of sufficient whiteness and high chemical purity is also valuable as a mineral filler, i.e., in paint, plastics, paper, rubber, carpet backing, vinyl tile, roofing materials (Guillet and Kreins, 1984) and as building and ornamental stone. This allows for the possibility of a multi-use, dolomitic-marble, mining operation in the Labrador City area.

In November, 1985, the Department of Mines and Energy invited proposals for further exploration and development of the dolomite deposits in the two Exempt Mineral Lands blocks. In January of 1986, the Department accepted a proposal from the Iron Ore Company of Canada to carry out additional drilling on both deposits with the intention of mining dolomitic marble by the summer of 1986 for use in the production of self-fluxing pellets.

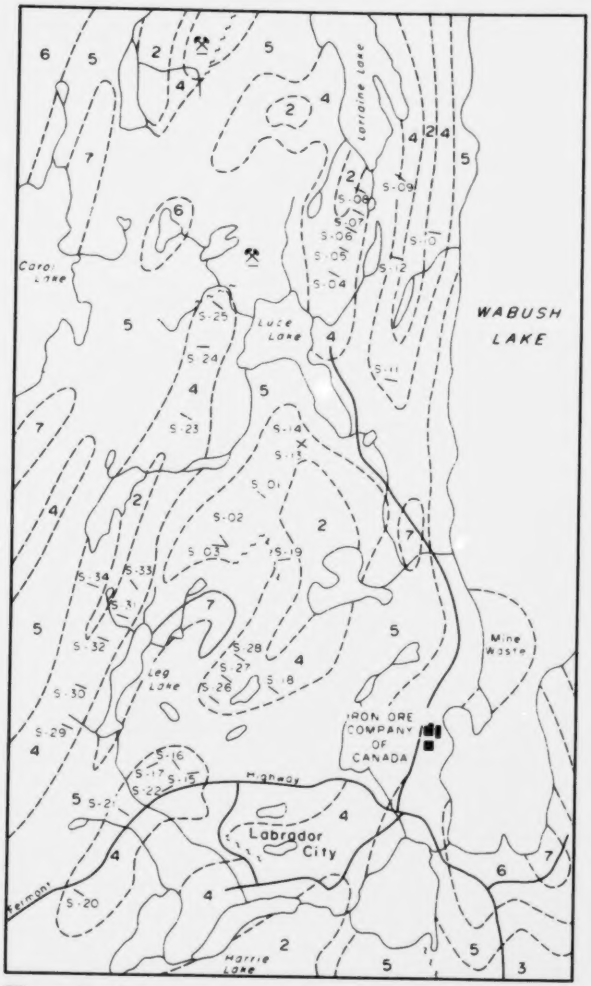
Silica - Labrador West

The 1984 industrial mineral survey confirmed that the white quartzite ridges immediately to the north and west of Labrador City are particularly pure and represent significant reserves of high quality silica. The quartzite ridges vary in size from 100 to 3000 m in length, 10 to 700 m in width, and they have up to 100 m of vertical relief. During the 1984 sample program, chip samples were collected from sections measured perpendicular to the strike of the best exposed ridges. The sections were divided into 7 to 10 m intervals and rock chips were collected every 0.5 to 1 m. A total of 383 samples were collected from 33 sections measuring 25 to 500 m in length.

The results of the 1984 sample program are summarized in Table 2. Averages of most of the sampled sections are presented, along with the number of samples and a location index for each section (Figure 5). From these results it is clear that many of the sampled ridges contain quartzite which meets, or exceeds, the specifications for the manufacture of silicon, ferrosilicon, silicon carbide (carborundum), refractory brick, all types of glass (including fiberglass) (Harben, 1977), ceramics, and mineral fillers. Distance from markets and the resulting transportation costs may preclude viability in many of these industries. However, since little or no beneficiation of the quartzite is needed and the infrastructure for mining and transportation is already in place, perhaps a more finished product could be marketed. The possibilities include 'speciality sands' (very pure silica sand), ferrosilicon, silicon metal, the melting of silica and growth of optical-grade crystals, artificial abrasives, and the new 'high tech' ceramics.

Silica - Big Pond

Large quartz and quartz-feldspar veins intrude massive to poorly foliated, granite to granodiorite of Neohelikian (or earlier) age, in an area situated 20 to 25 km west-southwest of Mary's Harbour. Three, large, discontinuously exposed, northeast-trending vein systems were originally mapped by K.E. Eade of the Geological Survey of Canada in 1961, and examined by Brinco in 1982. A silica survey, consisting of a one week detailed sampling program, was carried out during the 1985 field season and concentrated on the southeastern vein system (Figure 6).


WABUSH LAKE
Lorraine Lake
Carol Lake
Luce Lake
Leg Lake
Mine Waste
IRON ORE COMPANY OF CANADA
Highway
Labrador City
Vermont
Harrie Lake
S-01
S-02
S-03
S-04
S-05
S-06
S-07
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2
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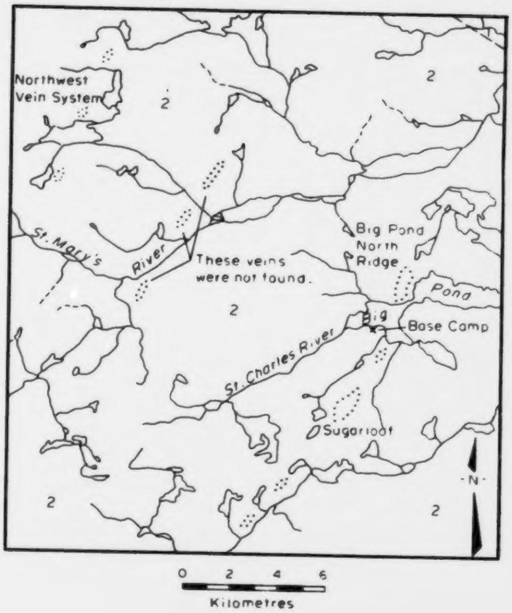
4
5
6
7

Figure 5: *Location of sections, e.g., S-16, sampled across quartzite ridges in Labrador City area. See Figure 2 for Legend.*

The southeastern vein system consists of five separate ridges, spaced up to 2 km apart in a north-northeast-trending line. They are up to 1500 m in length, 400 m in width, and are generally steep-sided with a maximum relief of 150 m. The two largest and most intensely sampled ridges are named the Sugarloaf and Big Pond North Ridge. The ridges are composed of quartz and feldspar veins displaying abundant evidence of multiple intrusion and brecciation. The breccia fragments range from large and angular to small and subrounded. Hematite-stained mylonites (Eade, 1962) are present as well.


Northwest Vein System
St. Mary's River
These veins were not found.
Big Pond North Ridge
Pond
Big
Base Camp
St. Charles River
Sugarloaf
N
2
0
2
4
6
Kilometres

LEGEND

⁘ Quartz-feldspar veins

2 Massive to poorly foliated granite to granodiorite

1 Granite and banded gneiss

Figure 6: *Location map of Big Pond silica survey (geology after K. E. Eade, 1962).*

The feldspar veins are light to dark orange and exhibit pegmatitic to microgranitic textures. Hematite and magnetite inclusions are common, and many feldspar veinlets are bordered with a dark-red hematite stain. Green epidote alteration is present in fractures within some of the feldspar fragments, and bright-orange potassium feldspar (adularia?) was observed in very late veins that are spatially associated with a vuggy texture in Big Pond North Ridge. Some of these features suggest the possibility that hydrothermal systems were operating in these vein systems; selected samples will be tested for precious metals.

Clean, white, quartz veins are exposed over a 10 to 30 m wide zone that parallels the steep, southeastern flank of Sugarloaf. This is a very favourable situation for quarrying should the prospect become economically viable. The quartz is massive in outcrop and may be a single large intrusion or a series of coalescing veins. The pure quartz zone grades across strike to the northwest into massive quartz containing very light-pink silicified fragments and/or bands. This second zone of less-pure quartz grades into a mixture of dominantly feldspar and minor quartz veining. To the southeast, the boundary of the pure quartz zone is not exposed and the possibility of a wider zone could be considered. Sugarloaf is the only sampled ridge within the three major vein systems that has a wide enough zone of pure quartz to be considered a good silica prospect.

Table 2. Average chemical analyses for sections sampled across quartzite ridges (see Figure 5)

Section	No. of Samples	SiO_2	Al_2O_3	Fe_{tot}	MgO	CaO	Na_2O	K_2O	TiO_2	MnO	P_2O_5	LOI	Total	SiO_2 calc.
S-01	3	99.47	0.10	0.10	0.01	0.01	0.01	0.02	0.02	0.01	0.01	0.22	99.97	99.49
S-02	22	99.08	0.09	0.05	0.01	0.01	0.01	0.02	0.01	0.01	0.02	0.28	99.56	99.49
S-03	23	99.10	0.13	0.07	0.02	0.03	0.02	0.03	0.01	0.01	0.02	0.27	99.67	99.40
S-04	7	99.05	0.06	0.03	0.01	0.02	0.01	0.01	0.01	0.01	0.02	0.34	99.53	99.48
S-05	4	99.09	0.10	0.06	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.25	99.53	99.52
S-06	8	99.40	0.10	0.06	0.01	0.02	0.01	0.02	0.01	0.01	0.01	0.18	99.81	99.56
S-07	11	99.36	0.08	0.17	0.02	0.02	0.01	0.01	0.01	0.01	0.02	0.26	100.04	99.38
S-08	6	99.10	0.08	0.51	0.02	0.04	0.01	0.01	0.01	0.02	0.02	0.33	100.11	98.96
S-09	6	99.12	0.12	0.23	0.01	0.02	0.01	0.02	0.01	0.01	0.02	0.18	99.71	99.36
S-10	5	98.62	0.22	0.28	0.12	0.15	0.01	0.04	0.02	0.01	0.02	0.44	99.92	98.69
S-11	10	98.47	0.27	0.60	0.08	0.03	0.01	0.03	0.02	0.01	0.02	0.23	99.75	98.69
S-12	7	97.57	0.64	0.88	0.16	0.05	0.10	0.13	0.02	0.02	0.03	0.32	99.90	97.65
S-13	14	99.18	0.08	0.03	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.20	99.53	99.61
S-14	14	98.95	0.14	0.12	0.01	0.01	0.01	0.03	0.01	0.01	0.02	0.23	99.50	99.41
S-15	5	98.57	0.10	0.10	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.22	99.05	99.50
S-16	6	99.10	0.13	0.03	0.01	0.01	0.01	0.02	0.01	0.01	0.01	0.20	99.51	99.55
S-17	4	93.66	4.93	0.10	0.02	0.01	0.01	0.26	0.02	0.01	0.01	0.43	99.45	94.20
S-18	8	99.14	0.23	0.06	0.02	0.01	0.01	0.05	0.01	0.01	0.01	0.31	99.82	99.28
S-19	5	98.73	0.12	0.06	0.01	0.04	0.01	0.02	0.01	0.01	0.03	0.22	99.22	99.48
S-20	4	93.49	3.47	0.46	0.23	0.05	0.03	0.23	0.11	0.01	0.03	0.78	99.86	94.61
S-21	6	98.83	0.26	0.08	0.02	0.02	0.01	0.06	0.03	0.01	0.02	0.28	99.59	99.22
S-22	4	98.66	0.22	0.04	0.02	0.03	0.01	0.01	0.01	0.01	0.02	0.33	99.32	99.32
S-23	10	98.12	0.38	0.18	0.03	0.06	0.12	0.05	0.01	0.01	0.01	0.31	99.27	98.83
S-24	7	99.31	0.13	0.16	0.02	0.02	0.01	0.02	0.01	0.01	0.01	0.26	99.93	99.35
S-25	10	98.72	0.23	0.39	0.03	0.04	0.01	0.02	0.03	0.02	0.01	0.19	99.66	99.03
S-26	27	99.15	0.06	0.09	0.02	0.02	0.01	0.01	0.01	0.01	0.01	0.22	99.59	99.53
S-27	26	98.88	0.23	0.09	0.02	0.03	0.03	0.05	0.02	0.01	0.01	0.27	99.59	99.25
S-28	16	98.86	0.28	0.11	0.02	0.02	0.01	0.05	0.02	0.01	0.01	0.22	99.59	99.25
S-29	3	99.19	0.10	0.07	0.02	0.02	0.01	0.02	0.03	0.01	0.01	0.17	99.62	99.55
S-30	6	98.81	0.30	0.09	0.03	0.05	0.08	0.05	0.03	0.01	0.04	0.30	99.75	99.05
S-31	7	99.01	0.10	0.15	0.02	0.02	0.01	0.02	0.02	0.01	0.02	0.24	99.61	99.38
S-32	6	99.33	0.08	0.15	0.02	0.03	0.01	0.02	0.02	0.01	0.02	0.27	99.90	99.39
S-33	51	99.09	0.10	0.21	0.02	0.02	0.02	0.02	0.02	0.01	0.01	0.25	99.74	99.32
S-34	6	99.10	0.11	0.03	0.01	0.03	0.01	0.01	0.02	0.01	0.01	0.25	99.57	99.50

Numerous short traverses were conducted across the ridgetops, perpendicular to strike, collecting chip samples at 10 to 15 m intervals, depending on the degree of exposure. One hundred and forty-four samples were collected from the southeastern vein system, and ten samples were collected from reconnaissance sampling of the northwestern vein system. The middle vein system of Eade (1961) has no observable topographic expression and was not located in this survey.

Goose Bay Anorthosite Complex

The Goose Bay anorthosite complex was investigated for its industrial mineral potential. It was studied as a potential source of alumina and assessed for dimension stone. The most recent geological mapping of the Goose Bay anorthosite complex is by Ryan *et al.* (1981), and Wardle and Ash (1984, *this volume*).

Grab samples obtained in 1984 indicate that the Goose Bay anorthosite contains up to 27 percent alumina. Alumina is one of the major volume materials used in 'high-tech' ceramics (Dickson, 1985); (high purity silica, zirconia, beryllia and yttria are others). For this usage, alumina must be obtained from unweathered crystalline rocks as opposed to residual deposits, i.e., bauxite. It was the aim of this reconnaissance survey to see if large areas of accessible anorthosite containing this grade of alumina could be delineated. In this initial investigation of road and hillside outcrops in the Goose Bay - Northwest River area, it was determined that the anorthosite contains 2 to 10 percent coarsely crystalline pyroxene and ilmenite. These mineral phases would dilute the Al_2O_3 content, and would be contaminants of large bulk samples, thus limiting the alumina potential of the anorthositic rocks.

The impurities mentioned above would also limit the dimension-stone potential of the Goose Bay anorthosite. Their irregular distribution detracts from the consistency and aesthetic appearance of the stone, and upon exposure to air they tend to oxidize and stain polished surfaces on finished slabs of rock. In addition, the outcrops are cut by closely spaced joint and fracture systems which prevent the extraction of large blocks, and large (1 to 3 cm long) feldspar crystals within the rock are commonly cut by annealed fractures that now appear as irregular, 1 to 2 mm wide, wavy white lines.

The aesthetic appeal of a good dimension stone is extremely important and is dependent on color, grain size and uniformity of texture. The stone must have a 'fashionable' appearance that will catch the eye of architects, as well as being hard, durable, strong, and resistent to environmental damage (Allison, 1984).

Nain Anorthosite Complex

The Nain anorthosite complex (Taylor, 1975, 1979) was investigated to assess its dimension stone potential. The well known localities containing gem-quality labradorite (Watson, 1980) were briefly assessed at Tabor Island, Pearly Gates and John Hay's Harbour. These are generally extremely coarse grained, pegmatitic pods that are either too limited in size or too fractured to allow quarrying in large uniform blocks. However, three other localities of massive, more homogenous, fine to coarsely crystalline (0.5 to 4 cm long crystals) anorthosite were visited and have much better dimension-stone potential (Figure 7).

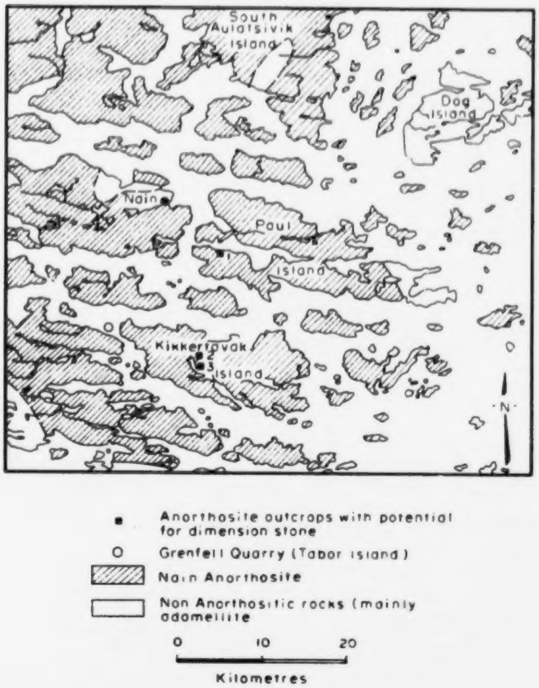

South Aulatsivik Island
Dog Island
Nain
Paul Island
Kikkertavak Island
1
2
3
N
● Anorthosite outcrops with potential for dimension stone
○ Grenfell Quarry (Tabor Island)
▨ Nain Anorthosite
☐ Non Anorthositic rocks (mainly adamellite)
0
10
20
Kilometres

Figure 7: *Location map of dimension stone sites in the Nain anorthosite complex.*

A large area of very massive anorthosite rises steeply for 75 to 100 m up from the shoreline at Ten Mile Bay. In the early sixties, Brinex and an independent granite producer from Quebec extracted several tonnes of stone at this site. Quarrying was extremely difficult on the steep, glacially-smoothed slopes due to a lack of jointing and proper 'benches' from which the drilling and extraction process could begin. The anorthosite has a medium-gray color, providing an ideal background for the deep, purplish-blue chatoyancy of the labradorite crystals, which are uniformly distributed throughout the rock. The anorthosite is medium grained (0.5 to 1.5 cm long crystals), has no visible xenoliths, and contain only minor large feldspar phenocrysts. It does contain, however, parallel pyroxene-biotite laminae and thin white lineations (1 to 3 mm wide) that are unevenly distributed through certain parts of the outcrop. These features detract from the overall appearance of the stone at Ten Mile Bay, and in combination with the difficulty of quarrying on steep slopes, reduce the dimension-stone potential of the site.

Massive, gently sloping outcrops of anorthosite occur on the east side of Igiak Bay and, to the north, in the 'saddle' between Igiak Bay and John Hay's Harbour. The anorthosite is coarse grained (1 to 4 cm long crystals), contains minor amounts of mafic minerals, and is free of any white lineations. Within the rock there is a uniform distribution of rich, dark-blue to blue-green chatoyant crystals, giving it a relatively consistent appearance. There is a distinct lack of vertical jointing and fracturing at the Igiak Bay locality, whereas in the 'saddle' locality, a vertical fracture-joint system is well developed. Both areas appear to have enough horizontal jointing for the quarrying of large blocks of anorthosite, which would be suitable for use as high-quality, chatoyant dimension stone similar to the Scandinavian 'blue pearl'. Drilling and quarrying of test blocks from these and other areas is being planned for the 1986 field season.

SUMMARY

The industrial mineral potential in Labrador is just beginning to be appreciated and evaluated. In western Labrador there are dolomitic marble deposits that meet the chemical specifications for self-fluxing iron ore pellets, and they may play an important role in the future of the iron ore industry, which is so important to the province. Very pure deposits of quartzite just outside Labrador City meet the requirements for a variety of silica-based industries, and both the quartzite and the dolomitic marble may have potential as mineral fillers and whiteners.

A silica prospect near Mary's Harbour in southeastern Labrador occurs where massive quartz-feldspar veins outcrop within 20 km of tidewater. These veins may also have precious metal potential. Investigations of the Goose Bay and Nain anorthosite complexes were initiated to evaluate their potential as sources of alumina and dimension stone. There are several very massive exposures of anorthosite in the Nain area which have high dimension stone potential, and warrant the drilling and quarrying of test blocks during the 1986 field season.

ACKNOWLEDGEMENTS

The dimension stone assessment was helped tremendously by the assistance and experience of Suzie Nantel of the Ministere de l'Energie et des Ressources du Quebec.

Lenny White is thanked for his capable and enjoyable field assistance throughout the summer. Henry Simpson of Labrador Mining and Exploration provided much help and advice during the western Labrador drill program, which was carried out by his drillers, Junior Strickland, Jerome Strickland and Stan Young.

Living accommodations and/or tent and trailor sites were kindly provided by Al Pittman in Steady Brook, Al Roper in Labrador City, and Winston White in the Nain area.

Logistical support, was provided by Sid Parsons and Ted Hall during our brief stay on the island, and by Wayne Tuttle and Ken O'Quinn in Labrador.

Ambrose Howse is thanked for critically reviewing the paper.

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LETITIA LAKE PROJECT: PROGRESS REPORT

R.R.Miller
Mineral Deposits Section

INTRODUCTION

The Letitia Lake area is located in Labrador, 160 km northwest of Goose Bay and 50 km east of the Smallwood Reservoir (Figure 1). It has been the focus of sporadic mineral exploration activity since the discovery of several Nb-Be showings (Mann #1 and Mann #2) in the late 1950's (Brummer, 1957). The aim of this project is to study the metallogeny of the Mann-type Nb-Be mineralization, in order to aid in the further evaluation of these deposits, and to develop criteria to explore for similar mineralization in Labrador.

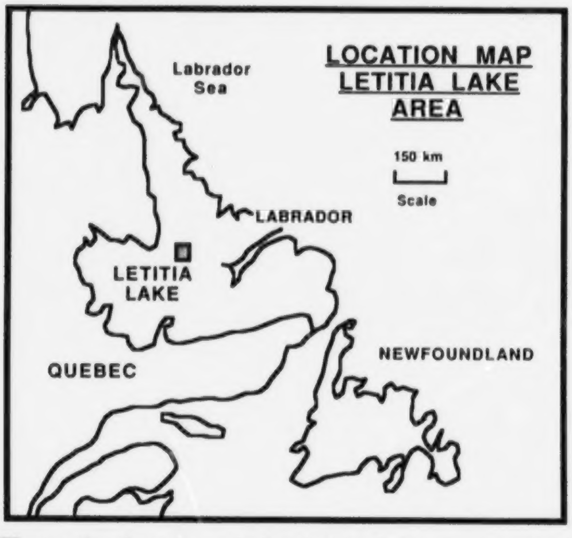

Figure 1: *Location of the Letitia Lake area, central Labrador.*

LETITIA LAKE RARE METAL SHOWINGS

Five weeks were spent in the Letitia Lake area, in the summer of 1985, to sample and map the Mann #1 showing and to visit some of the lesser known showings. A helicopter-borne spectrometer survey was also carried out over the Letitia Lake area to help locate other Mann-type showings.

The Mann #1 showing was mapped on a scale of 1:580 and the surrounding area was mapped on a scale of 1:2,320. Representative lithogeochemistry and petrographic samples were collected from each map area for future laboratory analysis (samples are presently being prepared for analysis). Regions contained on each map have been outlined on the geology sketch map of the Letitia Lake area (Figure 2).

Results from the spectrometer survey (total counts) will be released at a later date along with the results of a later ground check of significant radiometric anomalies; correlation of survey results indicate that the Mann-type showing has above background radioactivity, although not all radiometric anomalies can be attributed to this type of mineralization. Previously described showings in the area (Figure 2) were clearly indicated by the survey. These include:

Mann #1 Showing	*Be 001
Michelin Prospect	*Nb 001
Mann #2 Showing	*Nb 002
Two Tom Lake Showing	*Ree 001

Mapping of the rocks around all four previously known showings indicates that peralkaline syenites are the main rock type associated with the mineralization. Five centres of peralkaline syenite ± granite have been identified in the area; four have associated mineralization at or near their margins. Preliminary conclusions suggest that some or all of these five intrusive centres were the focus of the volcanic activity which resulted in the Letitia Lake Group peralkaline volcanic rocks; previous work suggests that all peralkaline rocks in the vicinity are coeval (Thomas, 1981; Hill and Thomas 1983). The four mineralized peralkaline centres are in the upper part of the Letitia Lake Group volcanic sequence near the contact with the younger Seal Lake Group. The apparently unmineralized peralkaline centre is near the base of the Letitia Lake Group and contains a significant proportion of peralkaline granite.

ACKNOWLEDGEMENTS

This report is based on field work carried out in the summer of 1985. Campbell Churchill carried out the duties of field assistant and Wayne Tuttle and Ken O'Quinn supplied the logistical support from Goose Bay. The campsite, helicopter and field equipment were shared with Martin Batterson, Quaternary Geology Section, and John McConnell, Geochemistry Section. Diagrams presented in this report were designed and constructed by the author using an Apple Macintosh microcomputer, laser printed by MRI Printing Services and photographically prepared for reproduction by Ken Byrne and assistants.

This project is a contribution to the Canada-Newfoundland Mineral Development Agreement, 1984-1989

* Newfoundland Department of Mines and Energy Mineral Inventory File numbers for NTS 13L/1

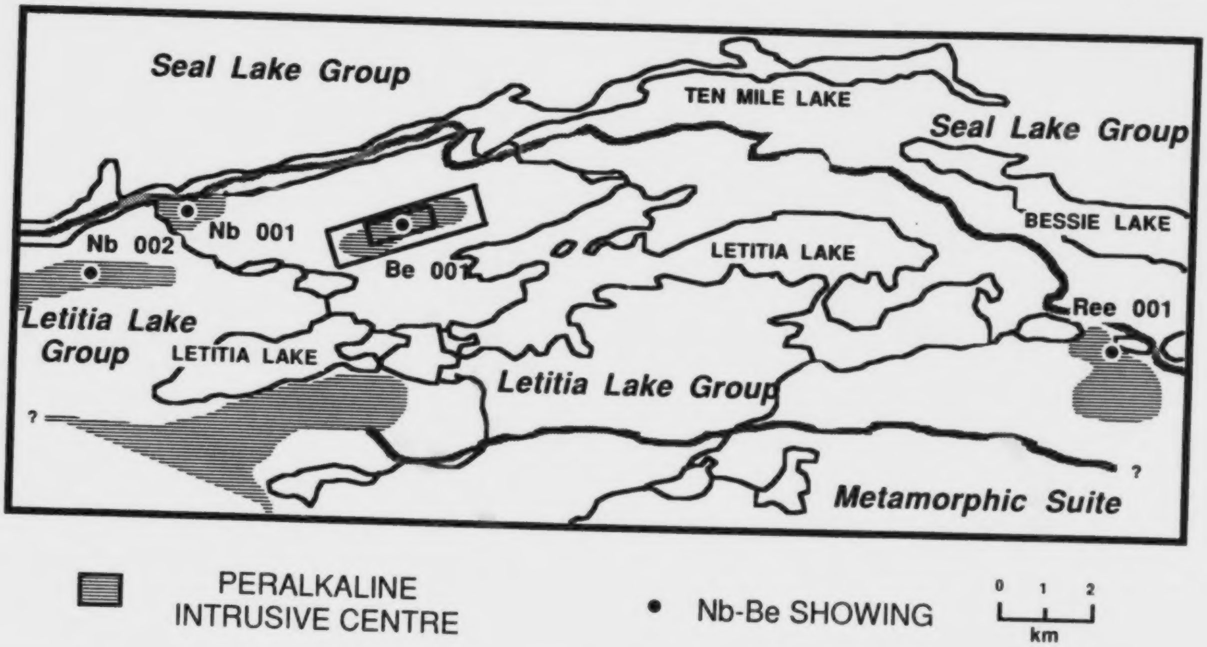
Seal Lake Group
TEN MILE LAKE
Seal Lake Group
BESSIE LAKE
Nb 001
Nb 002
Be 001
LETITIA LAKE
Letitia Lake Group
LETITIA LAKE
Ree 001
Letitia Lake Group
?
Metamorphic Suite
?
▤ PERALKALINE INTRUSIVE CENTRE
● Nb-Be SHOWING
0 1 2
km

Figure 2: *General geology and location of Nb-Be showings in the Letitia Lake area.*

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GEOLOGY OF THE STRANGE LAKE ALKALIC COMPLEX AND THE ASSOCIATED Zr-Y-Nb-Be-REE MINERALIZATION

R. R. Miller
Mineral Deposits Section

ABSTRACT

The Strange Lake Alkalic Complex is located on the Quebec-Labrador border in northern Labrador. It contains substantial quantities of Zr, Y, Nb, Be and REE, which are concentrated in lenses and veins of fine grained and pegmatitic granite.

Petrographic and mapping studies have identified three major subdivisions of the riebeckite ± aegirine granite, based on the volume percent of exotic minerals (many of which are ore minerals). These subdivisions are: exotic-poor (<5 percent exotic minerals), exotic (5 to 10 percent exotic minerals) and exotic-rich (>10 percent exotic minerals). The spatial relationships between these subdivisions are illustrated in cross-section and plan views of the complex. Age relationships, as indicated by field evidence, indicate that the exotic mineral contents increase with decreasing age.

The comparative chemistry of the subdivisions reflect the exotic mineral contents, as most incompatible elements, including Zr, Be, Y, Nb, and Th, increase in concentration with differentiation; REE concentrations and patterns also follow this trend.

Mineralization at Strange Lake occurs in the most exotic mineral enriched phases, which are late stage and enriched in incompatible elements. Concentrations of many elements are economically interesting.

INTRODUCTION

The Strange Lake Alkalic Complex (SLAC) is a peralkaline granite complex which hosts significant quantities of Zr, Y, Nb, Be and REE mineralization. It is truly 'strange', as it contains unique mineralogical assemblages, including several rare and un-named minerals, and is extremely enriched in many incompatible elements. To date, several other 'Rare Metal Granites' have been reported in the literature, e.g., Thor Lake (Trueman *et al*., 1985) and the Saudi Arabian occurrences (Drysdall *et al*., 1984), but none of these other occurrences have the unusual mineralogy and chemical signature of the Strange Lake deposit.

The complex is located on the Quebec-Newfoundland border approximately 250 km northeast of Schefferville, Quebec, and 150 km west of Nain, on the Labrador coast (Figure 1). It underlies an area, southeast of Lac Brisson, of approximately 32 km². The discovery, by the Iron Ore Company of Canada in 1979, resulted from follow-up work on a F in lake water and U in lake sediment anomaly, discovered in a regional survey carried out in 1978 under the Canada-Newfoundland Uranium Reconnaissance Program (Geological Survey of Canada / Newfoundland and Labrador Department of Mines and Energy, 1979). Part of this regional anomaly, about 20 km down-ice from the bedrock source, was due to the extensive glacial dispersal train from the alkalic complex. Boulder tracing within this dispersal train led to the bedrock discovery.

This is a progress report of work being done on the complex and also a summary of publicly available assessment reports by Iron Ore Company of Canada personnel (Hlava and Krishnan, 1980; Venkatswaran 1981). Other work includes a preliminary report on the complex by Currie (1985) and Miller (1985).

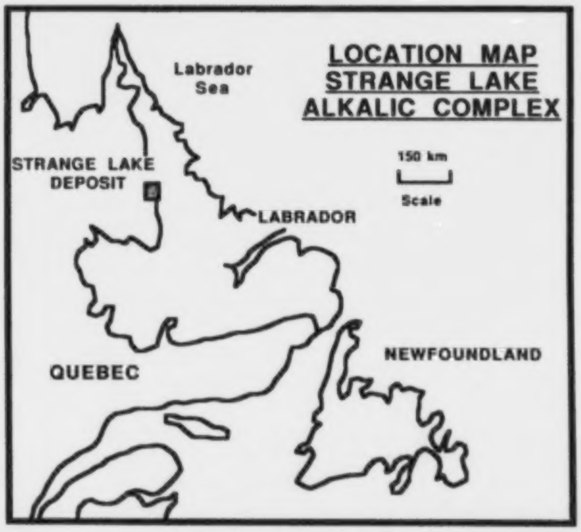
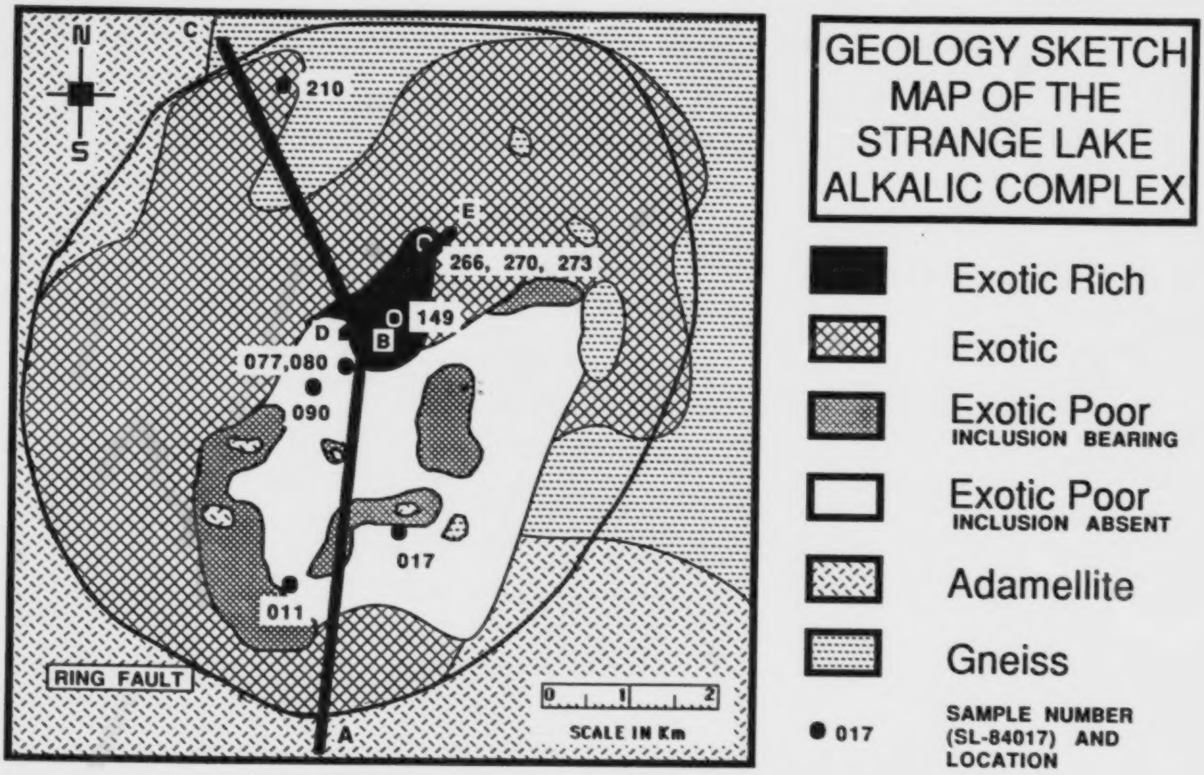


Figure 1: *Location of the Strange Lake deposit.*

This project is a contribution to the Canada-Newfoundland Mineral Development Agreement, 1984-1989


N
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SCALE IN Km
GEOLOGY SKETCH MAP OF THE STRANGE LAKE ALKALIC COMPLEX
Exotic Rich
Exotic
Exotic Poor INCLUSION BEARING
Exotic Poor INCLUSION ABSENT
Adamellite
Gneiss
● 017 SAMPLE NUMBER (SL-84017) AND LOCATION

Figure 2: *Generalized geology of the Strange Lake Alkalic Complex with sample locations and cross section lines.*

GEOLOGY

The Strange Lake Alkali Complex occurs within the Churchill Province (Taylor, 1975), but is intrusive into, and much younger than, the surrounding rocks, as indicated by field relationships and a K/Ar date on amphibole (1270 ± 30 Ma; Zajac *et al.*, 1984). Adamellite (quartz monzonite) forms the country rock on the southern and western contacts, and also occurs as small inclusions and roof pendants in the northeastern portion of the complex (Figure 2). A suite of gneisses, including amphibolites, quartzites and quartzofeldspathic gneisses, occurs in the contact area to the north and east, and also as inclusions and roof pendants in the northeastern portion of the complex.

The occurrence of roof pendants, discrete pegmatites, chilled contacts and discrete inclusions, indicate that the present erosion surface intersects the roof zone of a high level intrusive body. The occurrence of a circular or ring fault (dipping outwards 20 to 35°; Zajac *et al.*,1984) around the complex (indicated by drilling and VLF-EM data) also corroborates these conclusions. This ring fault is often filled by a fluorite ± hematite breccia matrix and veinlets, and occurs within the surrounding host rocks, commonly less than 20 m from the contact.

All of the granite in the complex is peralkaline as indicated by the ubiquitous presence of riebeckite ± aegirine (commonly forms pseudomorphs after riebeckite). The feldspars consist of either albite + K-feldspar, or microperthite. The exotic minerals[1], which generally total >10 percent of the mode, include elpidite ($Na_2ZrSi_6O_{15}\cdot 3H_2O$) and gittinsite ($CaZrSi_2O_7$). Other exotic minerals include: pyrochlore ($[Ca,Na]_2[Nb,Ta]_2O_6F$), armstrongite ($CaZrSi_6O_{15}\cdot 2\frac{1}{2}H_2O$), gadolinite ($Y_2Fe^{+2}Be_2Si_2O_{10}$), fluorite ($CaF_2$), kainosite ($Ca_2[Ce,Y]_2\,Si_4O_{12}[CO_3]\cdot H_2O$), allanite ($[Ce,Ca,Y]_2\,[Al,Fe^{+3}]_3[SiO_4]_3[OH]$), sphene ($CaTiSiO_4\,[O,OH,F]$), zircon ($ZrSiO_4$) and thorite ($ThSiO_4$). Several 'un-named' minerals also occur.

Granites that occur within the complex can be subdivided into several units based on texture, e.g., grain size, absence or presence of fine grained, more-mafic inclusions, and the percentage of exotic minerals (Figure 3). The three main subdivisions are based on the percentages of exotic minerals observed:

Exotic-poor	(<5%, EP)
Exotic	(5 to 10%, locally up to 15%; Ex)
Exotic-rich	(>10%; ER)

Table 1 lists some estimated modal ranges of representative samples of the main subdivisions. Note that the percentage of exotic minerals is usually dominated by gittinsite and/or elpidite.

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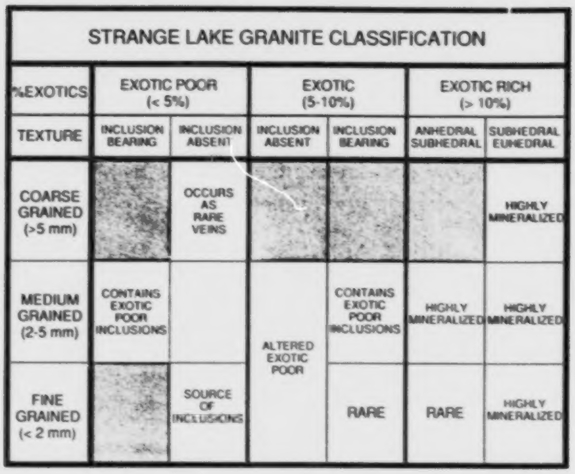
[1] Exotic minerals are defined for the Strange Lake Alkali Complex as all unusual, rare and/or previously unknown minerals that are enriched in incompatible elements.



STRANGE LAKE GRANITE CLASSIFICATION						
%EXOTICS	EXOTIC POOR (< 5%)		EXOTIC (5-10%)		EXOTIC RICH (> 10%)	
TEXTURE	INCLUSION BEARING	INCLUSION ABSENT	INCLUSION ABSENT	INCLUSION BEARING	ANHEDRAL SUBHEDRAL	SUBHEDRAL EUHEDRAL
COARSE GRAINED (>5 mm)	▨	OCCURS AS RARE VEINS	▨	▨	▨	HIGHLY MINERALIZED
MEDIUM GRAINED (2-5 mm)	CONTAINS EXOTIC POOR INCLUSIONS		ALTERED EXOTIC POOR	CONTAINS EXOTIC POOR INCLUSIONS	HIGHLY MINERALIZED	HIGHLY MINERALIZED
FINE GRAINED (< 2 mm)	▨	SOURCE OF INCLUSIONS		RARE	RARE	HIGHLY MINERALIZED

Figure 3: *Classification scheme for the Strange Lake peralkaline granite, based on texture and percent of exotic minerals. The shaded areas represent categories for which examples have not been observed. See the text for more details.*

TABLE 1. Estimated Ranges in the Modes of the Major Units of the Strange Lake Alkalic Complex

	Exotic Poor	Exotic	Exotic Rich
Quartz	15 - 60	30 - 60	25 - 60
Microcline	0 - 15	<5	<10 - 45
Microperthite	0 - 70	20 - 40	<10
Albite	0 - 5	<5 - 25	<10
Amphibole	0 - 10	3 - 15	0 - 8
Aegirine	<5	<5	0 - 10
Pyrochlore	TR	<0.5	<1
Elpidite	0 - TR	0 - 5	0 - 5
Gittinsite*	0 - TR	3 - 10	3 - 20
Zircon	0 - TR	<1	<2
Sphene	TR	0 -<1	<1
Fluorite	<1	<1	<2
Astrophyllite¹	TR	<2	0 - 5
Opaques	TR	TR	TR
% Exotics	<5	5 - 10	10 - 25

NOTE: Modes are volume % estimates from thin section investigation.

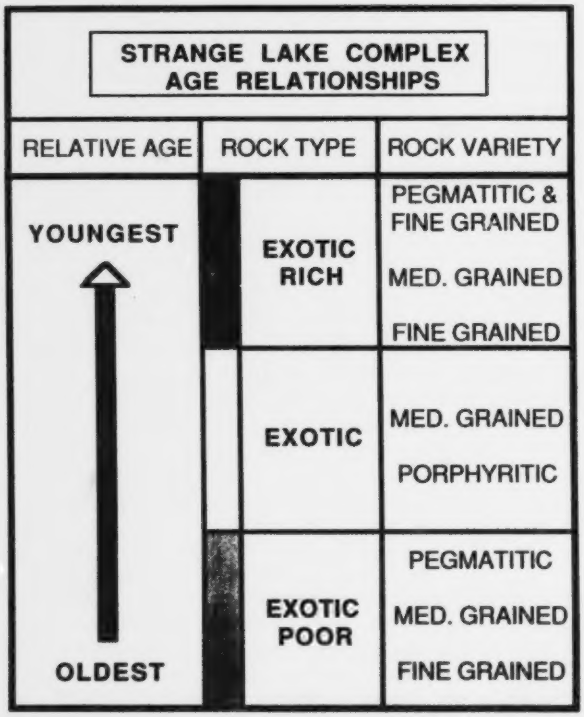
* volume % of pseudomorph of which gittinsite is the most abundant mineral (original mineral was most likely elpidite).

¹ 'astrophyllite' is a sphene + quartz + fluorite pseudomorph after possible astrophyllite.

The exotic-poor (EP) subdivision consists of a suite of rocks ranging from very fine grained (<0.5 mm), through fine grained (0.5 to 2 mm) and medium grained (2 to 5 mm), to pegmatitic (>5 mm). Discrete inclusion-bearing units, surrounding host rock roof pendants, can also be mapped. These units contain 5 to 50 percent rounded to subrounded (0.01 to 2 m in diameter) inclusions of very fine grained, darker colored, EP granite. Crosscutting relationships and the occurrence of inclusions indicate that relative ages within the EP subdivision become younger from the very fine grained unit to the inclusion-bearing unit, and finally to the pegmatitic veins. Elpidite and gittinsite are not common in the EP granite (Table 1).

Rocks classified in the exotic (Ex) subdivision are characterized by the presence of inclusions similar to those described in the EP granite. The two textural varieties that have been mapped are a massive medium grained variety and a finer grained amphibole porphyritic variety. These varieties contain inclusions of very fine grained EP granite (similar to that described in the EP inclusion-bearing unit) and, in the case of the medium grained variety, porphyritic Ex inclusions; thus, the porphyritic variety is the older. The porphyritic variety also has lower exotic mineral contents (5 to 10 percent compared to 10 to 15 percent) and lower ZrO_2 contents (1.25 to 1.8 percent compared to 1.8 to 2.2 percent). Most of the ZrO_2 in the Ex rocks occurs in elpidite, gittinsite and zircon.

The exotic-rich subdivision (ER) can be broken down into rocks containing subhedral to euhedral gittinsite and/or elpidite, and those containing anhedral to subhedral gittin-



STRANGE LAKE COMPLEX AGE RELATIONSHIPS		
RELATIVE AGE	ROCK TYPE	ROCK VARIETY
YOUNGEST	EXOTIC RICH	PEGMATITIC & FINE GRAINED
		MED. GRAINED
		FINE GRAINED
	EXOTIC	MED. GRAINED
		PORPHYRITIC
	EXOTIC POOR	PEGMATITIC
		MED. GRAINED
OLDEST		FINE GRAINED

Figure 4: *Illustration of the age relationships between the various subdivisions (ROCK TYPE) and varieties of the Strange Lake peralkaline granite. These relationships are based on field observations.*

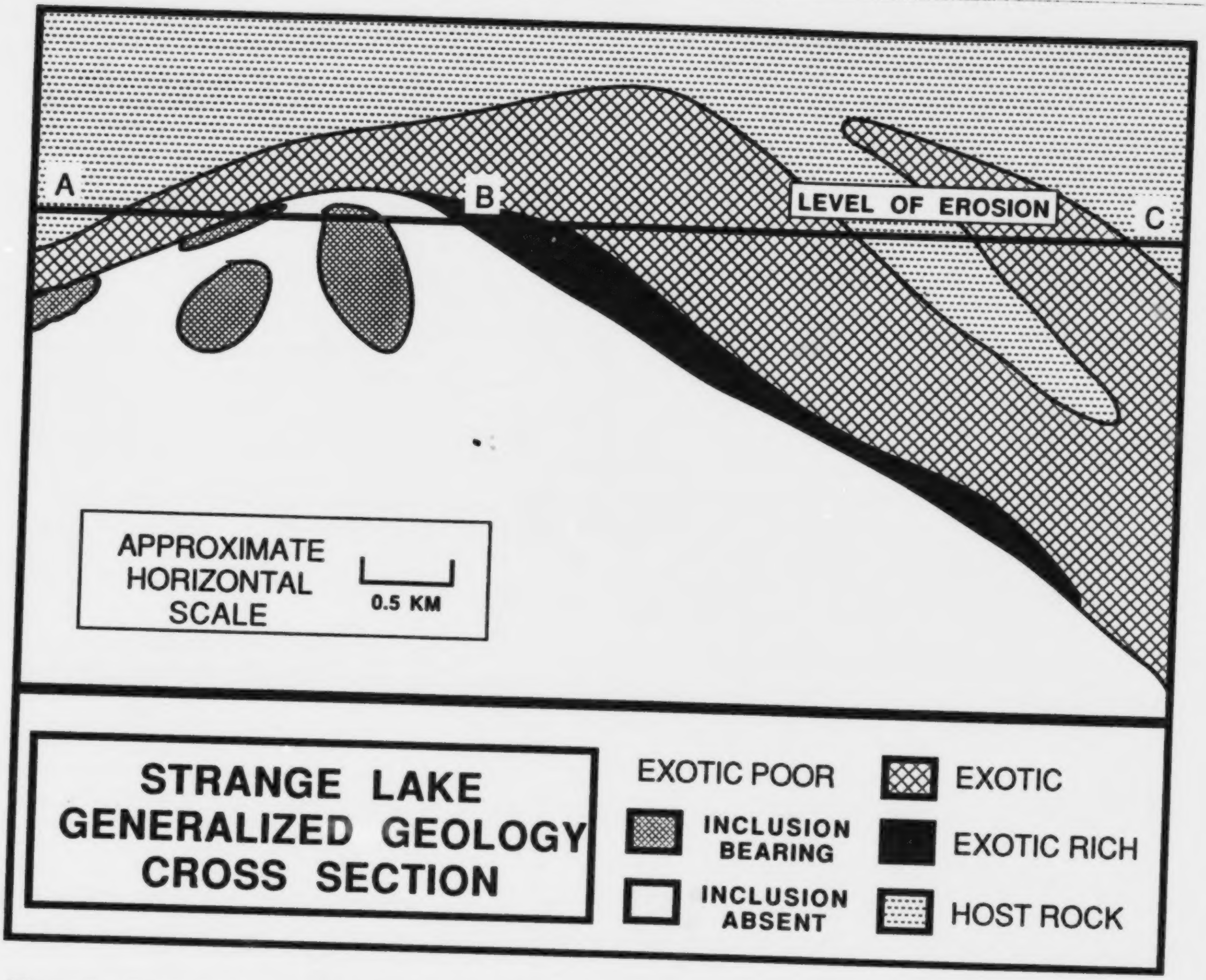


Figure 5: *Generalized geological cross section of the Strange Lake Alkalic Complex (Section ABC on Figure 2).*

site and/or elpidite. Each of the two subgroups can be further subdivided into fine grained (<2 mm), medium grained (2 to 4 mm) and riebeckite porphyritic varieties, with the subhedral to euhedral group also having a pegmatitic (>4 mm) variety. The anhedral to subhedral group is the more abundant and appears to be the older, based on the occurrence of crosscutting dikes and veins of the subhedral to euhedral group within the main intrusion of the anhedral to subhedral group. The younger group also contains higher concentrations of Zr as well as Y, REE, U, Th, Nb, and F.

Crosscutting relationships between the major subdivisions indicate that the EP unit is the oldest and the ER unit is the youngest. This indicates increasing exotic mineral contents with decreasing age, a trend that is also observed within each subdivision. Figure 4 illustrates the age relationships between the various granite types (subdivisions) and textural varieties.

Mapping of the complex (Figure 1), including outcrop and drill core data, indicates the following relationships between the subdivisions:

1) The EP granite occupies approximately 12 km in the south-central portion of the complex.

2) The Ex granite, dominated by the medium grained variety, occupies 22 km^2 of the complex and almost completely surrounds the EP granite, with the exception of the southwestern corner of the complex.

3) Most of the ER granite, dominated by the medium grained anhedral to subhedral group, occurs in the north-central portion of the complex at the contact between the EP and Ex units, where it occupies approximately 1 km^2.

4) Small ER veins and dikes (<0.5 m thick) intrude the Ex unit, the EP unit and roof pendants throughout the complex.

5) An extensive zone of ER veins and dikes, cutting EX granite, occurs in the northwestern part of the complex.

Some of these relationships are illustrated in Figure 5.

GEOCHEMISTRY

Preliminary results are now available from major, minor and REE analysis of some of the representative samples collected from the Strange Lake Alkalic Complex. Some of these analyses are listed in Tables 2 and 3. Figure 6 illustrates the relationship between the various types of exotic granite and the variation of SiO_2 and Al_2O_3. Note that there is little systematic variation in SiO_2 contents between the varieties, while Al_2O_3 is lowest for the ER (youngest) and highest for the EP (oldest) rocks. Al_2O_3 was thus chosen as a variation index; the Al_2O_3 axis has been reversed to reflect decreasing age (increasing differentiation ?) toward the right.

Al_2O_3 variation diagrams for some of the elements are displayed in Figure 7. Some of the interesting points illustrated in these diagrams are:

1) MgO and CaO increase with increasing differentiation.

2) K_2O contents are relatively constant.

3) Na_2O increases with differentiation, although the peralkalinity trend remains fairly constant (Figure 8).

4) Be, ZrO_2 and Y_2O_3 increase with increasing differentiation.

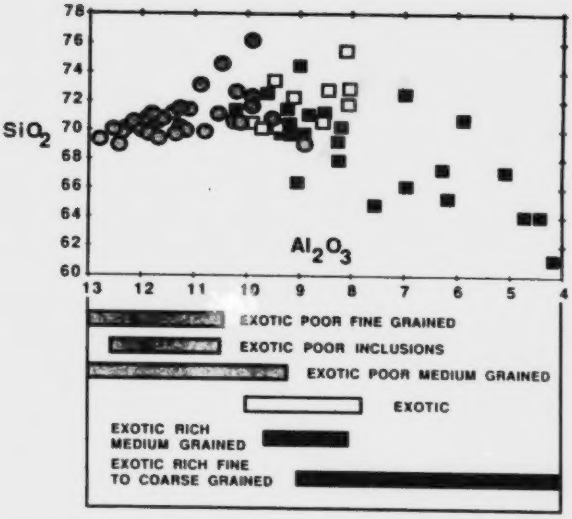


Figure 6: *Illustration of the variation of weight percent SiO_2 and Al_2O_3 with rock variety. Note that Al_2O_3 contents vary systematically with exotic mineral contents, while SiO_2 appears to vary relatively little. The Al_2O_3 axis is reversed to illustrate decreasing relative age towards the right.*

Table 2. Major and Minor Element Analyses of Representative Samples from the Strange Lake Complex

	EXOTIC POOR					EXOTIC		EXOTIC RICH		
	SL-84017 Inclusion	SL-84273 Inclusion	SL-84090 Fine Grained	SL-84011 Medium Grained	SL-84071 Medium Grained	SL-84266 Porphyritic	SL-84210 Medium Grained	SL-84080 Fine Grained	SL-84270 Pegmatitic	SL-84149 Fine Grained
SiO_2	69.95	69.75	70.45	71.05	72.60	70.30	75.45	71.60	67.20	65.35
TiO_2	0.16	0.28	0.24	0.28	0.25	0.40	0.27	0.29	0.08	0.49
Al_2O_3	12.52	11.89	11.78	11.34	10.21	9.70	8.07	9.23	5.07	6.18
Fe_2O_3	1.50	2.02	3.68	1.72	1.91	2.61	2.40	2.67	2.43	3.26
FeO	2.58	2.45	0.31	3.09	2.72	2.57	1.09	1.89	0.01	0.13
MnO	0.07	0.14	0.06	0.10	0.12	0.17	0.15	0.11	0.15	0.18
MgO	0.04	0.14	0.03	0.02	0.09	0.30	0.09	0.02	1.31	1.42
CaO	0.79	1.21	1.11	0.39	0.22	1.87	1.40	1.39	8.05	5.36
Na_2O	4.93	4.54	6.61	5.49	4.91	4.29	2.78	4.82	0.55	1.10
K_2O	6.26	5.88	3.72	4.54	4.57	4.02	4.24	3.41	4.27	5.62
P_2O_5	0.01	0.01	0.02	0.02	0.02	0.03	0.03	0.04	0.04	0.17
ZrO_2	0.31	0.54	0.49	0.58	0.69	1.73	2.29	2.07	0.69	2.38
Y_2O_3	0.10	0.12	0.07	0.08	0.21	0.27	0.37	0.32	2.02	3.33
Nb_2O_5	0.03	0.05	0.06	0.04	0.13	0.15	0.16	0.15	0.18	0.88
BeO	0.01	0.01	0.01	0.01	0.05	0.04	0.04	0.06	1.45	0.61
H_2O	0.11	0.04	0.50	0.37	0.68	0.47	0.50	0.50	2.23	2.10
CO_2	0.05	0.03	0.13	0.10	0.12	0.04	0.01	0.11	0.10	0.19
F	0.59	0.42	0.65	0.38	0.20	0.63	0.45	0.77	3.32	1.60
F=O	-0.25	-0.18	-0.27	-0.16	-0.08	-0.27	-0.19	-0.32	-1.4	-0.67
Total	99.76	99.34	99.65	99.44	99.62	99.32	99.60	99.13	97.75*	99.68
U	7.7	16.7	21.9	18.3	29.7	50.2	52.6	65.7	134.0	212.0
Th	32	47	91	101	134	163	227	375	2572	2350
Rb	774	1262	531	524	1074	1310	987	960	758	1771
Sr	15	31	48	3	9	72	35	22	266	445
Zn	342	753	365	432	903	803	1005	947	1681	1389

NOTE: Major elements, Be, and Zn were analyzed by A.A. method; F by Specific Ion Electrode Method and $CO_2 + H_2O$ by I.R. Method (Newfoundland Department of Mines and Energy); Th, Rb, Sr, Y, Zr, Nb by X.R.F. method (Memorial University X.R.F. Lab); U by neutron activation (Nuclear Activation Services Ltd.). All oxides and F in weight %; trace elements quoted as ppm.

* This sample contains 2.55 % REE.

STRANGE LAKE COMPLEX GEOCHEMICAL TRENDS

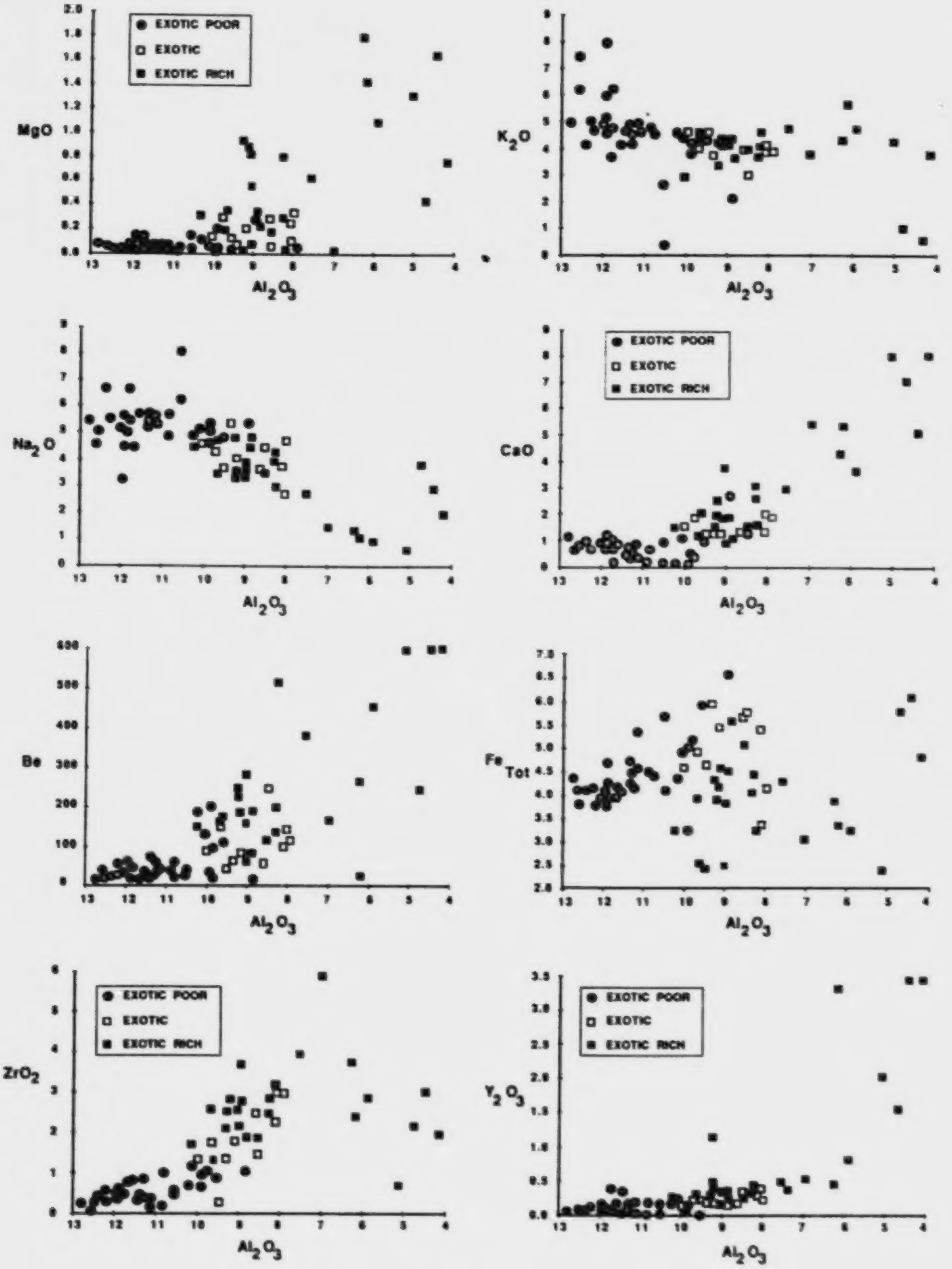


Figure 7: *Chemical variation diagrams for some of the more interesting elements at Strange Lake (71 samples). The symbols are the same for all of the chemical variation diagrams (Figure 6 also). All axes are labelled in weight percent except Be (ppm).* Fe_{tot}=total Fe as FeO

Table 3. REE Analyses of Representative Samples from the Strange Lake Complex

	EXOTIC POOR				EXOTIC			EXOTIC RICH		
	SL-84017 Inclusion	SL-84273 Inclusion	SL-84090 Fine Grained	SL-84011 Medium Grained	SL-84071 Medium Grained	SL-84266 Porphy-ritic	SL-84210 Medium Grained	SL-84080 Fine Grained	SL-84270 Pegma-titic	SL-84149 Fine Grained
La	499.7	558.3	530.2	677.6	2073.9	2266.8	1266.7	660.7	1409.5	2929.1
Ce	1161.3	1270.7	1229	1407.9	4786.5	5260.5	2904.7	1626.1	3352.6	7000.3
Pr	116.9	118.2	126.5	128.3	406.5	531.7	271.9	164.3	562.4	655.7
Nd	583.8	548.4	546.5	562.8	1755	2233.6	1186.6	701.8	2622	2635.2
Sm	144.6	136.3	125	117	432.6	510.4	263.9	202.4	1370.5	1313.5
Eu [1]	2.5	3.1	5.7	0.4	15	3	3.9	6.9	75.9	59.8
Gd	131.3	121.6	108.2	100.5	394.6	435.4	255.8	228.9	1837.9	2244.9
Tb [1]	11.7	26.8	17.7	24.3	53.8	60.6	65.7	45.2	377.6	598.4
Dy	109.8	155.7	93.5	131.5	340.9	407.4	377	354.2	2545	4549.1
Er	48.2	61.8	47.9	67.3	135	164.6	227.5	226.7	1026.6	2343.5
Yb [1]	22.7	35.7	32.2	42.2	72.1	74.9	163.2	166.6	454.2	1191.3
Total REE	2832.5	3036.6	2862.4	3259.8	10465.9	11948.9	6986.9	4383.8	15634.2	25520.8
Ce/Yb	51.16	35.59	38.17	33.36	66.39	70.23	17.80	9.76	7.38	5.88
Eu/Eu*	0.0181	0.0240	0.0489	0.0037	0.0363	0.0063	0.0150	0.0320	0.0473	0.0336

NOTE: All analyses are given in ppm.

[1] Analyses for these elements usually have poor counting statistics (values > ± 10% at 90% probability) and thus poor precision. Ho and Lu have extremely poor counting statistics and a Tm tracer was used for the analysis, thus these elements have not been listed. Analyses by the REE Lab at Memorial University of Newfoundland (B. Fryer supervising); thin film X.R.F. method.

5) Fe_{tot} increases with increasing differentiation within the EP group but decreases for the overall suite.

6) In most cases, the trends are continuous from EP to ER granites, i.e., increase with exotic mineral contents.

7) ZrO_2 best differentiates between the three subdivisions;EP:0.15 to 1.25 percent ZrO_2; Ex:1.25 to 2.2 percent ZrO_2; ER:2.2 to 4.0 percent ZrO_2.

The significance of each of these observations is not fully understood, as these studies are ongoing, but it appears that the fractional crystallization of a Na+Al rich mineral could account for the decrease of Na_2O and Al_2O_3, and the increase in incompatible elements, e.g., Be and Zr.

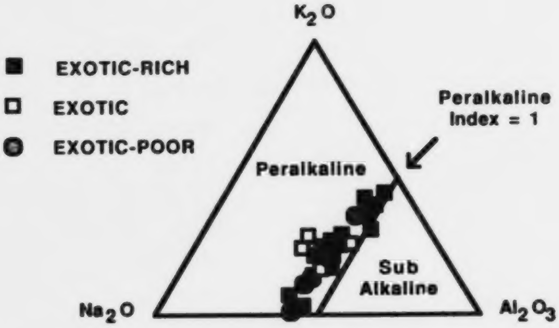


Figure 8: *This ternary diagram illustrates the relationship between molecular proportions of the elements used to calculate the peralkaline index ($K_2O + Na_2O/Al_2O_3$); all samples that lie to the left of the line, where the peralkaline index equals 1, are peralkaline.*

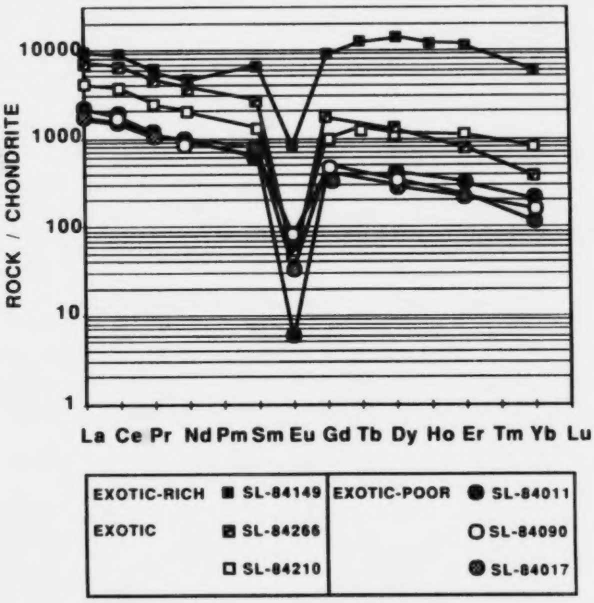


Figure 9: *Chondrite normalized diagram for representative samples from the Strange Lake peralkaline granite. Note that the more exotic-rich samples have higher total rare earth contents and are heavy rare earth enriched relative to the more exotic-poor samples.*

The REE patterns of all of the peralkaline granites exhibit negative Eu anomalies (Eu/Eu* <0.05) and high individual REE values (Table 3) ranging from 100 to 10,000

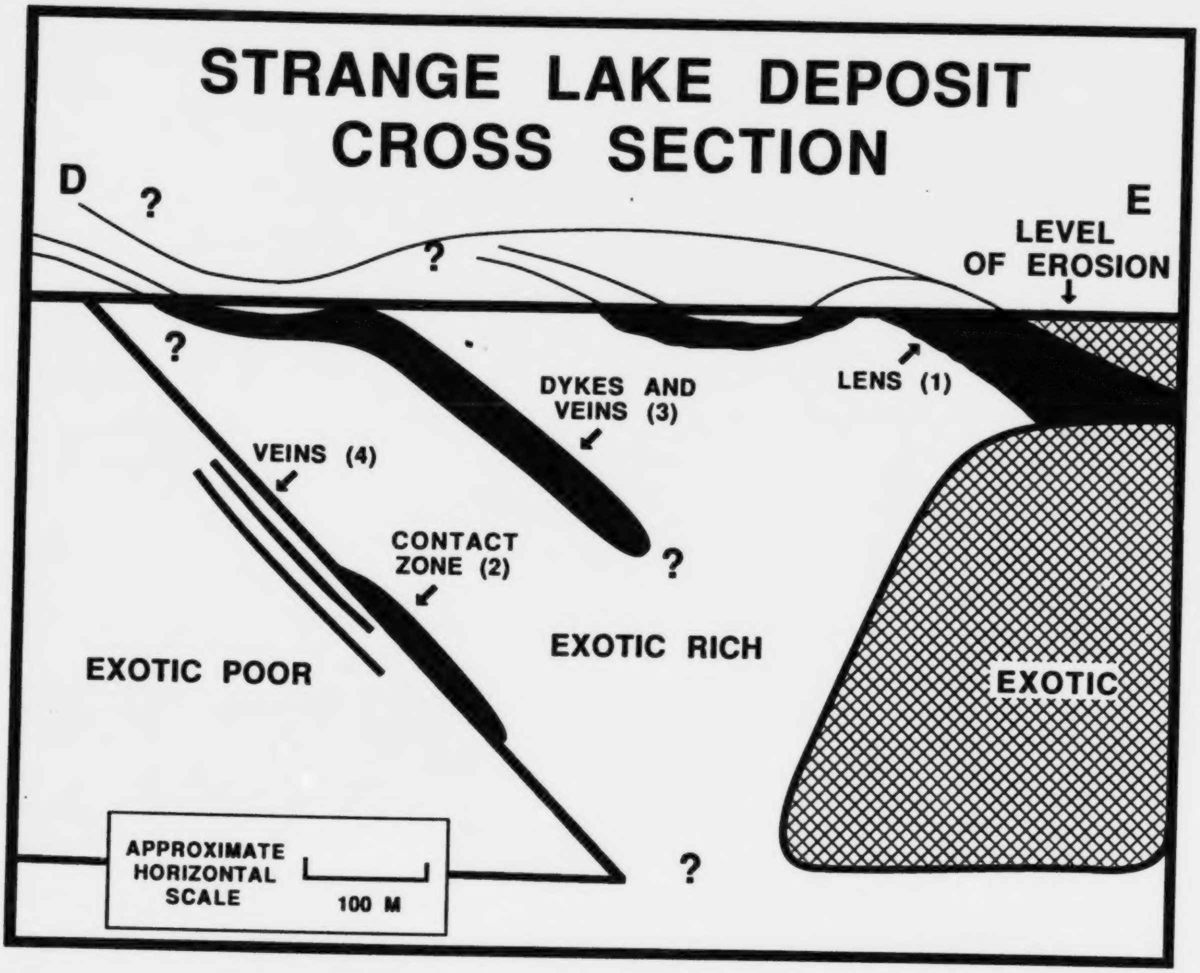


Figure 10: *Generalized cross section of the main exotic-rich intrusion (Section DE on Figure 2), illustrating the location of the highly mineralized zones. The four kinds of mineralization, mentioned in the text, have been illustrated on this cross section.*

C.N. (chondrite normalized; Figure 9). As indicated above, the REE values (incompatible elements) become higher as the percentage of exotic minerals increases, i.e., from EP to ER granites. The proportions of HREE (represented by Yb) to LREE (represented by Ce) also follow this trend as indicated by the value Ce/Yb, which decreases from approximately 50 in EP granites to 6 in the highly mineralized ER granites, i.e., HREE increase relative to LREE.

MINERALIZATION

All of the mineralized zones in the complex occur within, and are classified as, ER granite (Figure 10). In fact, this granite has such elevated abundances of Zr-Y-Nb-Be-REE that the entire unit could be considered as potentially economic. The medium to high grade zones occur in the lenses and dikes of the subhedral to euhedral varieties of ER; the most enriched unit is an approximately 10 m thick, fine grained, and pegmatitic ER lens. In most cases, the pegmatitic units carry the highest values of Y, Nb, Be and REE, whereas Zr is quite variable throughout the ER granites. These highly mineralized zones of ER granite occur as (Figure 10):

1) lenses which extend from the main ER intrusion into the surrounding Ex granite
2) pegmatitic (subhedral to anhedral) and fine grained ER zones on some of the upper and lower contacts of the main ER intrusion
3) either subhedral to euhedral pegmatitic and fine grained veins or pegmatitic veins cutting the main ER intrusion
4) small veins and dikes mostly pegmatitic, cutting the EP unit in the footwall of the ER intrusion.

CONCLUSIONS

At this stage of the study of the Strange Lake Alkalic Complex, it is difficult to present a petrogenetic model, although enough data are available to deduce some aspects of a model. For instance, we know that the alkalic granite crystallized in a high level environment. The high concentrations of volatile elements, such as F, Na and K, suggest that the magma chamber did not have a conduit to the surface. The exotic and exotic-rich granite must have been derived from exotic-poor granite magma at a lower crustal level by a complicated process, which probably involved enrichment through fractional crystallization, thermo-gravitational diffusion and the formation of a fluorine-rich, relatively water-poor, vapour phase. The origin of the magma responsible for the exotic-poor granite is a part of the model which requires more data before a reasonable hypothesis can be proposed.

Ongoing and future work will focus on producing:

1) a model of the evolution of the complex and the associated mineral deposits

2) an exploration case history/exploration strategy for 'Strange Lake type' granites and their associated mineral deposits

ACKNOWLEDGEMENTS

This report is based on field work carried out in the summer of 1984. Dave Molloy aptly carried out the duties of field assistant and Wayne Tuttle and Ken O'Quin supplied the logistical support from Goose Bay. The campsite, helicopter and field equipment were shared with Martin Batterson and Jerry Ricketts of the Quaternary Geology Section; this arrangement resulted in a lightened workload for all concerned. All charts and diagrams in this report were designed and constructed by the author using an Apple Macintosh microcomputer, laser printed by MRI Printing Services and photographically prepared for reproduction by Ken Byrne and assistants. The author gained substantial experience on, and understanding of, the Strange Lake Alkalic Complex while carrying out the drilling and exploration programs on the complex for the Iron Ore Company of Canada. The manuscript was improved by the comments of A. Kerr, J. Tuach and P. Dean.

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MARBLE ASSESSMENT - INSULAR NEWFOUNDLAND

A. F. Howse
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ABSTRACT

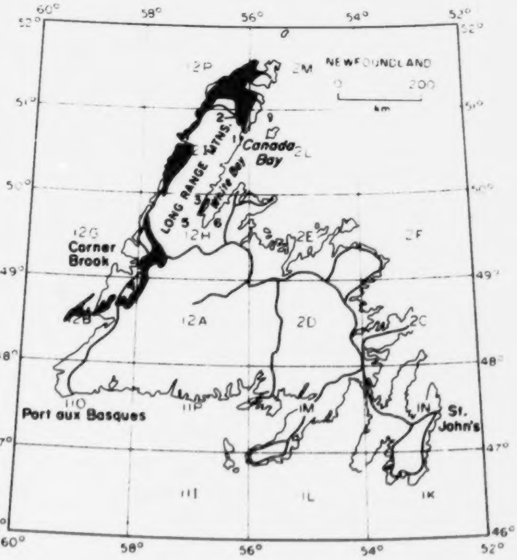
An assessment of Newfoundland's marble deposits was initiated in 1985. The project's aim is to determine the potential value of this marble for such industrial applications as fillers, whiteners and dimension stone.

Marble of potential commercial value occurs at a number of localities in western Newfoundland. At White Bay, deposits exist in the Cambro-Ordovician Coney Arm Group and in the Eocambrian White Bay Group. In the same area, a newly identified unit of marble and calc-silicate rocks occurs within the Precambrian terrane of the Long Range Mountains. White high-purity marble is found in the Ordovician St. George Group at several sites around Canada Bay on the Great Northern Peninsula. In and around Corner Brook, marble deposits are hosted by the St. George Group and Table Head Formation.

INTRODUCTION

Newfoundland's marble deposits initially attracted interest because of their potential commercial use in the building industry. Early attempts to quarry ornamental building stone from white marble deposits at Clay Cove in White Bay and Canada Harbour on the Great Northern Peninsula were unsuccessful (Edgar, 1928; Bain, 1937). Initial work by Muir (1935) and Howse (1936) on marbles in the White Bay and Canada Bay areas resulted in a more detailed study by Bain (1937) into the potential use of marble for dimension stone. Goudge (1965) explored the possibilities of producing terrazzo chips (for use in floor tiles) from marble deposits near Corner Brook and Sop's Arm. Further evaluation of Newfoundland marble deposits was carried out during larger surveys of the island's limestone resources, e.g., Lee (1956), McKillop (1963), Besaw (1973), DeGrace (1974). These studies were primarily concerned with identifying limestone and marble that are chemically suitable for such industrial applications as cement and quicklime manufacturing, together with metallurgical use.

Changes in the marble industry in recent years emphasize the need for this province to re-examine its marble resources. The most significant development is the increased demand for crushed and ground stone in industrialized countries, where this material far outranks dimension stone in terms of tonnage and value (Harbean and Bates, 1984). The uses for crushed and ground marble range from landscaping and terrazzo flooring to extensive application as mineral filler. Mineral fillers, in addition to providing bulk and strength to finished products, may also add and enhance certain attractive physical properties such as whiteness, brightness and smoothness. The purest and whitest grades of ground calcium carbonate are used in the production of paint, plastics and paper; lower grades are used in a diversity of products such as carpet backing, asphaltic compounds, putty, linoleum and rubber.



INDEX MAP

Figure 1: *Distribution of carbonate rocks in western Newfoundland (shaded area). Marble deposits were investigated at (1) Canada Bay (2) Roddickton (3) Sop's Arm (4) Corner Brook (5) Upper Humber River and (6) Purbeck's Cove.*

The main objectives of the 1985 project were to identify deposits of white high-calcium marble and to assess the variability of the marble's physical and chemical properties. Deposits in three broad geographical areas, White Bay, Canada Bay and Corner Brook (Figure 1), were sampled extensively. All samples collected during the 1985 field season have been sent to the Department of Mines and Energy

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This project is a contribution to the Canada-Newfoundland Mineral Development Agreement, 1984-1989

geochemical laboratory for chemical analyses. Selected representative samples are also being prepared for tests to determine their whiteness and brightness qualities. When the chemical and physical analyses are completed, the results will be released as an open file.

WESTERN WHITE BAY

On the west side of White Bay, clastic-carbonate rocks of the Cambro-Ordovician Coney Arm Group (Lock, 1969; Smyth and Schillereff, 1982, flank and unconformably overlie the Long Range Complex. A belt of mainly limestone and marble extends south from Cobbler Head for approximately 40 km (Figure 2). The carbonates are increasingly recrystallized and deformed southwards. Marble deposits near Sop's Arm have been considered as possible sources of ornamental building stone (Bain, 1937) and material for terrazzo flooring (Goudge, 1965). Large reserves of high purity limestone exist on the western shore of Great Coney Arm (Lee, 1956; Bedford, 1957). Recent road construction has greatly improved access to these areas, and in 1985 these deposits were re-examined to determine their potential for industrial uses. Descriptions of the deposits that were investigated during 1985 are given below.

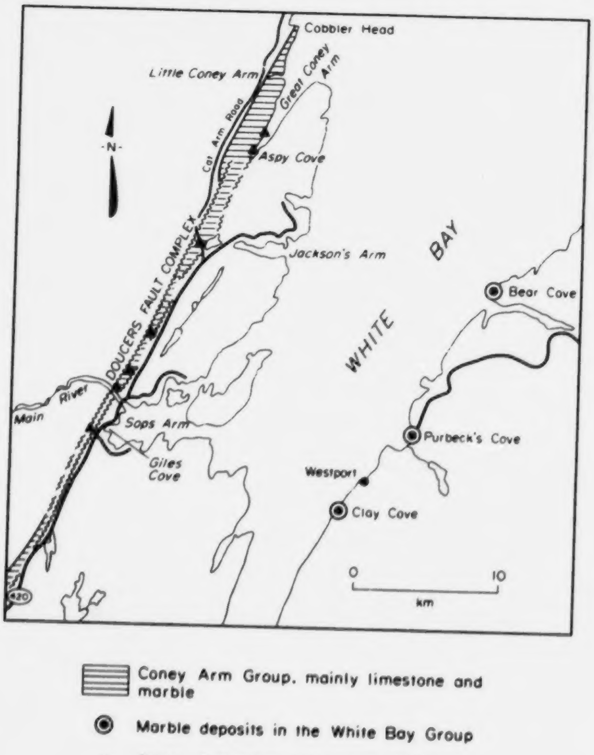


Figure 2: *Locations of marble and limestone deposits in the White Bay area.*

Sop's Arm - Jackson's Arm

Multicolored marble is exposed in a gravel quarry on the north bank of Main River, approximatly 100 m west of highway 420. The stone is a fine grained, cream-colored breccia cut by an extensive network of slender,wavy, reddish-brown and orange calcite veins, which impart a pale orange-brown color to the deposit. A 30 m wide, north-south trending, steeply dipping zone is exposed. It is bounded on the west by granite and on the east by shale, although the actual contacts with these rocks are not exposed. Irregular fractures occur throughout the exposure, but are more pronounced in its western parts. In the eastern part of the section, the marble is fine grained and homogeneous, but is cut by numerous veinlets of red calcite. The unsound, broken condition of the stone eliminates any potential this deposit has as a source of dimension stone. However, the marble is highly decorative and is thus a potential source of chips for terrazzo flooring, if significant reserves exist. Similar marble is sporadically exposed in a cliff that parallels Route 420, about 5 km north of Main River. The red-tinted stone contains pink, white and gray bands. It, too, is highly fractured, although the degree of fracturing is variable from outcrop to outcrop.

A great variation in color and texture is a characteristic feature of Sop's Arm marbles. South of Main River, for example, the marble is generally lighter coloured, more massive and more competent. An example of this can be seen on the west bank of Doucer's Brook, just 250 m west of Route 420 near Giles Cove. This deposit, which Bain (1937) considered as having the best dimension stone potential, has a uniformly light color and less pronounced veining than the material described previously. The relative hardness, abrasion resisting qualities, and attractive color of the marble favour its use as terrazzo chips. Any potential developer, however, will have to first prove the existence of significant tonnage of marble of uniform quality.

Marble breccia is exposed in a cliff near the southwest corner of a small pond about 2.5 km north of Main River, just west of the highway to Jackson's Arm. It has a very distinctive texture consisting of small dark gray marble clasts in a white calcite matrix. The fragments range up to 2 cm across and stand out prominently in the white calcite background. The outcrop is strongly fractured containing one set of vertically dipping joints trending 030 and another dipping subhorizontally into the outcrop. The marble tends to slab into vertical sheets along the vertical joints. Samples of this marble were cut with a tile saw and polished. The results indicate a unique, highly decorative stone which potentially could be used for such purposes as trophy bases and other small ornamental objects.

Coney Arm

Carbonate rocks of the Coney Arm Group are exposed, almost continuously, along the west shore of Coney Arm, White Bay. The rocks consist of dark gray, recrystallized limestone, dolostone and marble. After a brief reconnaissance survey, Lee (1956) estimated a reserve of some 187 million tonnes of limestone in the area. Bedford (1957) did a more selective and detailed study, which included some cross-sectional sampling. He concluded that the linear ridge along the coast between Coney Arm and Aspy Cove contained approximately 30 million tonnes of stone grading over 96 percent calcium carbonate and 1.20 percent magnesium carbonate. This is a conservative figure, based on a strike length of 1200 m and a maximum quarryable distance inland of 150 m. This reserve estimate was subsequently revised by Brinco Limited to over 46 million tonnes grading 97.1 percent $CaCO_3$ and 0.7 percent MgO. The limestone unit continues for several kilometres south of Coney Arm Bottom and is transected by the new Cat Arm access road, west of Jackson's Arm Pond. It is likely that the long linear ridge between the bottom of Coney Arm and Jackson's Arm Pond contains additional large reserves of limestone, although of undetermined quality. Extensive sampling for chemical and physical analyses was conducted in 1985 along the west coast of Coney Arm, and along the Cat Arm access road. The recrystallized limestone and marbles that were examined, are too dark for high-grade filler, however, they maybe suitable for possible industrial uses, such as cement manufacturing. These deposits are readily accessible and are situated close to a deep-water port.

In the course of this study, minor amounts of sphalerite and galena (estimated at 0.5 percent), were noted in thick bedded, recrystallized gray dolostone in a small area on the north shore of Little Coney Arm. The honey-colored sphalerite is finely disseminated in the dolostones. It resembles in style those occurrences recorded in platformal carbonate rocks on the northwest side of the Great Northern Peninsula, i.e., near the base of the Port au Port Group as described by Knight (1984). The occurrence, which was discovered by colleague John Tuach, is the first Pb-Zn showing found in the Coney Arm Group.

Upper Humber River

White to pale gray marble is exposed in cliffs along a woods road, which follows the north bank of the Upper Humber River about 10 km west of the Sop's Arm highway. The occurrences are part of a lens-shaped unit of marble and calc-silicate rocks mapped by Erdmer (1984), within the Precambrian terrane of the Long Range Mountains.

The marble is white gray or pale pink with green bands, is extremely coarse grained, and is strongly jointed and fractured. Banding in the marble trends 150 to 170 and dips steeply eastward. Minute flakes of mica with rusty haloes occur in the stone. Other impurities include graphitic and quartz-rich zones, which greatly detract from the stone's potential for use as a filler. Representative samples of the outcrops were collected for physical and chemical tests. Whiter and probably purer marble has been noted in this area (D. Reusch, personal communication, 1984; B. Mercer, personal communication, 1985), although these occurrences were not examined during the study. This marble unit may warrant further detailed assessment.

EASTERN WHITE BAY

Marble deposits occur within the Eocambrian White Bay Group at Purbeck's Cove, Clay Cove and Bear Cove on the western coast of the Baie Verte Peninsula (Hibbard, 1983). These deposits were investigated during the 1985 field season; descriptions of the individual deposits are given below.

Purbeck's Cove

White marble forms a cliff overlooking the north side of the community of Purbeck's Cove. The marble exhibits great variation in texture on both outcrop and hand specimen scale, and varies from extremely fine grained to coarsely crystalline. It is highly fractured and cut by conjugate joints. Although the exact size of the deposit is unknown because of structural complications and lack of exposure, a strike (040) length of 225 m of continuous marble was measured, with an average outcrop width of 9 m. Bain (1937) considered the marble to be unsuitable for building and ornamental stone because of the severe jointing. The marble may have potential as a filler and whitener. Small quantities of this stone have been used locally for agricultural lime.

Clay Cove

A deposit of white marble at Clay Cove, approximately 6 km south of Purbeck's Cove, was worked on a small scale in the late 1920's. The marble is grayish white to white, with local brown streaks, and varies texturally from aphanitic material to coarsely crystalline stone. A small brook which flows across the deposit has polished some of the quarried fragments to a brilliant white. The rocks are strongly jointed, but generally the degree of fracturing is less than other similar deposits in the area (notably the one at Purbeck's Cove). The size of the deposit could not be accurately determined because of lack of bedrock exposure. It was traced for 37 m along strike (180) and is at least 30 m wide; it has a block configuration. The deposit was sampled along its strike and dip (80 W); the results will provide the first analytical data for this marble prospect.

An exposure of blue marble underlies a point of land on the south side of Clay Cove. Projecting offshore, the bed strikes 030 and dips vertically. A central 4 m wide zone of black and blue-gray marble, containing white carbonate veinlets, is flanked by mixed blue marble and carbonate schist. This deposit is too small to be of any economic significance.

Bear Cove

Highly decorative crystalline marble and marble breccia are exposed in several localities on the west shore of Bear Cove, (a recently abandoned community, situated near the entrance to Western Arm). The small well exposed deposit at White Point is a pod-like structure surrounded on three sides by metaclastic rocks. Hibbard (1983, pages 35 to 36), thought the marble represents 'a debris flow, a channel or a depositional block', and suggested a similar origin for the deposits at Clay Cove and Purbeck's Cove. The latter deposits are significantly bigger and also appear to have a blocky configuration. The white marble at Bear Cove contains pink bands and is highly fractured. It has a very coarse texture and the deposit is flanked by carbonate-breccia. Similar carbonate-breccia float was observed near the Purbeck's Cove deposit.

CANADA BAY AREA

Commercial interest in the Canada Bay marble deposits began early in this century, when they were investigated as a potential source of ornamental building stone. Despite a long history of assessment by government and private in-

interests, the early attempts in 1913 by the Colonial Trading Company to quarry the Canada Harbour white marble deposits remain the only serious effort to exploit this resource. DeGrace (1974) has discussed the assessment history of the Canada Bay marble deposits and readers are referred to his detailed account for more background information. The white marbles of Canada Bay occur with bluish-gray marble in strongly deformed zones within parautochthonous St. George Group carbonates, which underlie the Hare Bay Allochthon (Knight, 1984). A zone containing scattered outcrops of white marble extends from an area approximately 3 km south of Canada Harbour northwards to Penny's Pond on the Conche road (Figure 3). All of the known occurrences were investigated in 1985; three of the most significant deposits are described below.

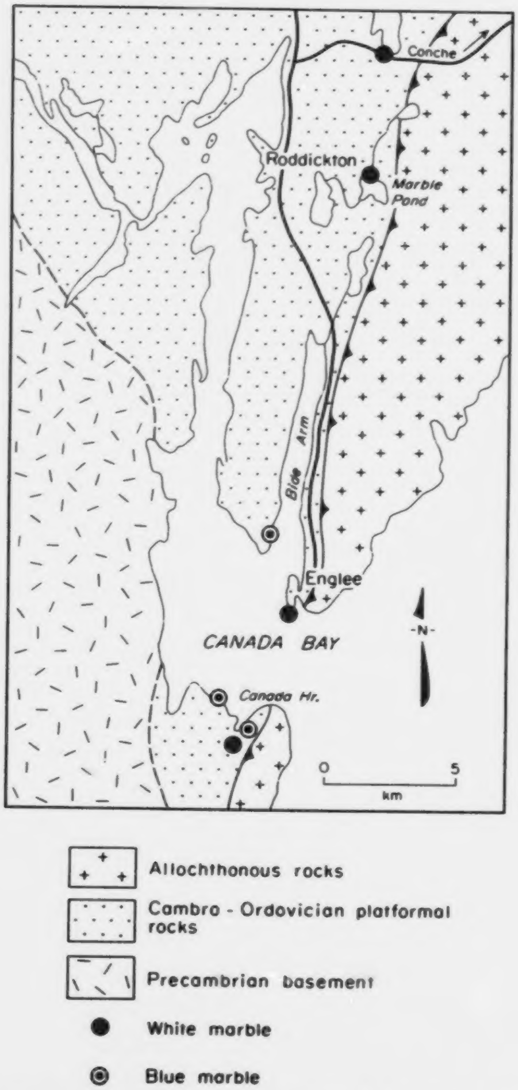


Figure 3: *Generalized map of Canada Bay area showing main geological elements and location of marble deposits.*

Canada Harbour Deposit

The Canada Harbour deposit is located approximately 250 m south of the abandoned settlement of Canada Harbour where it forms Marble Ridge, a prominent topographic feature. The white marble is gradationally overlain by blue-gray marble and dolomite. The deposit is structurally complex and bedding features are not apparent. Bain (1937) showed the white marble as occupying the core of an upright anticline, with the blue-gray marble on its flanks. The exact thickness of the white marble unit is unknown. In an old quarry near the crest of the hill, the unit is at least 20 m thick.

The marble is generally white, but is also ivory or cream and, in places, has a distinctive pink hue. It is extremely fine grained and breaks with a conchoidal fracture. Some of the whiter stone has a porcellaneous texture and breaks much more irregularly.

Impurities in the marble include chlorite and sericite, which occur as thin coatings along joints and bedding planes. Small amounts of quartz are also present. The deposit is also strongly fractured with joints that parallel and cross-cut the bedding. These features make the Canada Harbour deposit unsuitable as a source of building stone. However, the whiteness and high purity of some of the marble makes it a potential source of high-grade filler.

Marble Pond

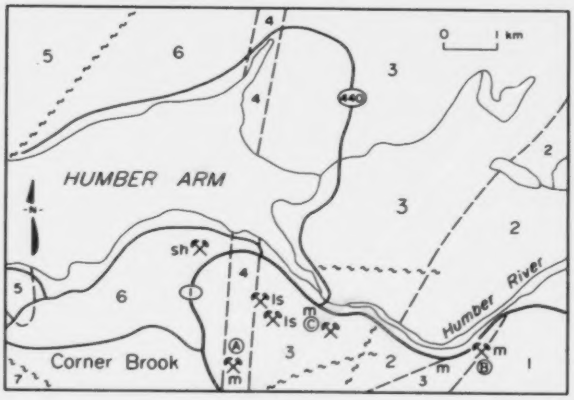
A deposit of white marble is exposed in the bed of Marble Brook, where it flows into Marble Pond, 3.5 km east of Roddickton. The flat-lying marble apparently extends southward beneath the pond and can be traced continuously northward along the brook for about 50 m. However, it sporadically outcrops along the brook for several hundred metres. The stone has a slightly gray cast, a finely crystalline texture, and breaks into thin slabs not more than 2 cm in thickness. Widely spaced vertical joints trend 340 to 250. The stone appears to be suited for tiles and other applications requiring flat, thin slabs.

Conche Road

White marble is exposed just north and south of the Conche highway (Route 432) about 3.5 km east of its junction with the main Roddickton-Englee highway (Route 433). The north-south trending, eastward dipping (50°) zone strikes across the highway and extends beneath Penny's Pond. The marble is also exposed in the bed of an access road that leads from Route 432 to Penny's Pond. The middle and top of the zone contains sections of high-purity, soft, white marble. Sections of cream-colored dolomitic marble are also present. In both locations, the marble is poorly exposed and it is difficult to estimate its width. However, south of the road, it is at least 50 m wide. North of the road, near Penny's Pond, samples were collected across a width of 22 m. These thicknesses are approximate because in both sites the contacts of the marble were not observed. The Conche Road deposit may be the most promising deposit in the Canada Bay area.

CORNER BROOK AREA

Carbonate rocks of the St. George Group in the Corner Brook area host several active and dormant quarries (Figure 4). Several quarries were visited, but only the Junction Quarry appears to contain marble with the degree of whiteness necessary for commercial use as filler. This quarry is located at the base of a 100 m cliff on the south side of the Trans Canada Highway, approximately 6 km east of Corner Brook. Between 1925 and 1943, limestone from the Junction Quarry was used in the local pulp and paper mill.



LEGEND

ALLOCHTHONOUS ROCKS

Cambrian

HUMBER ARM GROUP

7 Cooks Brook Formation
6 Irishtown Formation
5 Summerside Formation

AUTOCHTHONOUS ROCKS

Middle Ordovician

4 Table Head Group

Early Ordovician

3 St. George Group

Cambrian

2 Grand Lake Group

Late Precambrian to Ordovician

1 Mt. Musgrave Group

Limestone.......Ls
Marble.............m
Shale...............Sh
Dormston Quarry........A
L. House Quarry.........B
Junction Quarry..........C

Figure 4: *Local geology of the Corner Brook area including location of limestone and marble quarries.*

Coarsely crystalline white marble, together with black or dark gray and pink-banded marble, is exposed in a high vertical cliff wall at the Junction Quarry. The white marble section was sampled along approximately 15 m of the southwest quarry face. The whole sequence dips steeply northwestward, toward the highway.

A marble deposit of potential economic interest is exposed in the Dormston Quarry about 1 km southeast of Corner Brook. This dormant quarry is located in north-south striking, westerly dipping (60) beds of the Table Head Formation. The black, fine to medium grained marble has a tendency to break into cubic fragments which, according to Goudge (1977), could potentially yield terrazzo chips of extremely high quality.

ACKNOWLEDGEMENTS

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Mineral Development Division, Report 86-1, pages 27-38*

METALLOGENY OF NEWFOUNDLAND GRANITES - STUDIES IN THE WESTERN WHITE BAY AREA AND ON THE SOUTHWEST COAST

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ABSTRACT

Gold prospects in the Silurian Sops Arm Group, White Bay area, are briefly described, and it is suggested that they may have formed in epithermal-fumarolic environments. In addition, potential exists for gold mineralization associated with carbonate-altered ultramafic rocks along lineaments. A fluorite occurrence is described from the Devils Room Granite.

Molybdenite and fluorite occurrences are briefly described in the Isle Aux Morts Brook and Strawberry granites, southwest coast of Newfoundland. Anomalous radioactivity is present in the Peter Snout and Rose Blanche east granites. The gold-bearing environments in the Cape Ray area are summarized, and additional potential for gold is noted in the Port Aux Basques Gneiss and in the Bay Du Nord Group.

INTRODUCTION

A project on the metallogeny of Newfoundland granites was initiated in April of 1985. The objectives are to assist in the development of metallogenic models for granitoid mineralization in Newfoundland using a combination of geological, lithogeochemical, and isotope techniques. An essential part of the project is to document, and further define, all of the known granitoid mineralization on the island, and to identify additional plutons or areas which have potential to host granite-related mineralization. Commodities of interest are Sn, W, U, Mo, Bi, Be, Li, Sb, F, Ta, Zr, Y, Nb, Rare Earth elements, and Au.

The 1985 season was primarily spent investigating possible relationships between granitoid rocks and gold mineralization. Field work was conducted in the Sops Arm area during June, and on the Southwest coast during July and August (Figure 1). This work was performed on a reconnaissance basis, and therefore the comments presented below are subject to substantial modification as further data are obtained.

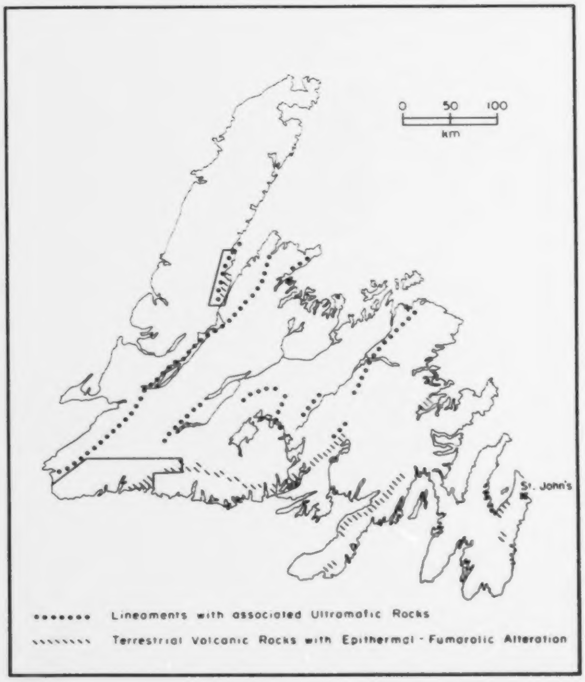
WESTERN WHITE BAY AREA

Introduction

The possible relationship of granitoid rocks to gold bearing epithermal-fumarolic systems is under investigation in the western White Bay area (Figure 2). A lithogeochemical survey of the plutonic rocks is in progress, and a suite of samples was collected to initiate a geochronological study. The geology of Paleozoic rocks in this area is summarized by Smyth and Schillereff (1981, 1982), and the geology of the Grenville terrane is described by Erdmer (1986). Figure 2 was drawn from these sources.

Jackson's Arm Area

Anomalous gold mineralization of possible Late Precambrian age, located on and near the Cat Arm access road west of Jackson's Arm, is described and discussed by Tuach and French *(this volume)*. The host to the mineralization and alteration is a late Grenvillian, foliated, megacrystic granodiorite, informally called the French-Childs granodiorite.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km
St. John's
•••••• Lineaments with associated Ultramafic Rocks
\\\\\\\\ Terrestrial Volcanic Rocks with Epithermal - Fumarolic Alteration

Figure 1: *Location of field areas. Also shown are areas with recognized potential to host lode and/or epithermal-fumarolic gold deposits.*

This project is a contribution to the Canada-Newfoundland Mineral Development Agreement, 1984-1989

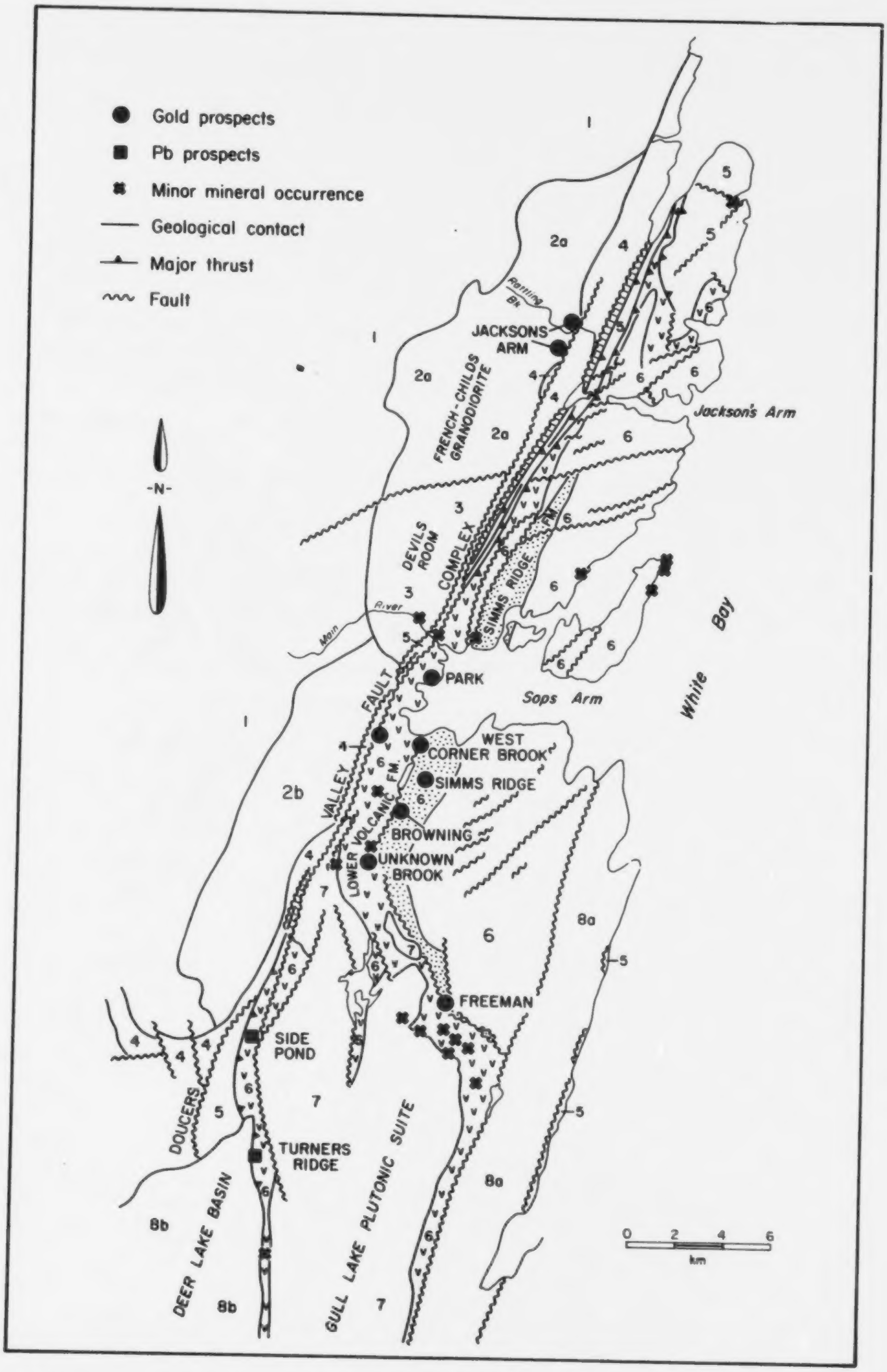
● Gold prospects
■ Pb prospects
✖ Minor mineral occurrence
Geological contact
Major thrust
Fault
-N-
Rattling Bk
JACKSONS ARM
Jackson's Arm
FRENCH-CHILDS GRANODIORITE
DEVILS ROOM
COMPLEX
SIMMS RIDGE FM
Main River
PARK
Sops Arm
White Bay
WEST CORNER BROOK
SIMMS RIDGE
BROWNING
UNKNOWN BROOK
VALLEY FAULT
LOWER VOLCANIC FM
FREEMAN
SIDE POND
TURNERS RIDGE
DOUCERS
DEER LAKE BASIN
GULL LAKE PLUTONIC SUITE
1
2a
2b
3
4
5
6
7
8a
8b
0 2 4 6
km

Figure 2: *Geology of the western White Bay area; after Smyth and Schillereff (1982) and Erdmer (1986). The Lower Volcanic Formation and the Simms Ridge Formation of the Sops Arm Group are patterned.*

LEGEND

UPPER PALEOZOIC (Basin Fill Sequences and Intrusions)

CARBONIFEROUS

8 8b, Deer Lake Group (Visean);
8A, Anguille Group (Tournasian)

DEVONIAN OR EARLIER?

7 Gull Lake Intrusive Suite

SILURIAN

6 Sops Arm Group

LOWER PALEOZOIC ALLOCHTHON

CAMBRIAN - MIDDLE ORDOVICIAN

5 Southern White Bay Allochthon—partially ophiolitic; mélange containing ultramafic blocks is cross-hatched.

LOWER PALEOZOIC AUTOCHTHON (Platform)

CAMBRIAN - MIDDLE ORDOVICIAN

4 Coney Arm Group

PRECAMBRIAN (Grenville basement)

LATE PROTEROZOIC(?)

3 Devils Room Granite[1] - massive, unfoliated.

MID PROTEROZOIC AND EARLIER (>1105 ± 90 Ma)

2 Massive to foliated, megacrystic, granitoid plutons
2a: French-Childs granodiorite; 2b: granite.

1 Leucocratic gneiss, amphibolite and gabbro.

Devils Room Granite

Fluorite mineralization occurs in the Devils Room Granite[1] as fracture coatings up to 1 cm thick, and in a fine grained silica-fluorite matrix to a 1 m wide, vertical tuffisite vein. The mineralization is developed in a medium to coarse grained, orange to red, equigranular phase of the granite which has been exposed in the new forest access road on the north side of Main River. Areas with white clay alteration up to 50 m wide are present in the new roadcuts. These features probably reflect a late stage, relatively low-temperature, hydrothermal event during cooling of the granite. Fluorite fracture coatings were also reported in the Devils Room Granite by Smyth and Schillereff (1982). A 1 m chip sample across the tuffisite vein returned an analysis of 15 ppb Au.[2]

The relationship of the Devils Room Granite, including its alteration and mineralization features, to the gold mineralization in the Jackson's Arm area is unknown. Possibilities are discussed by Tuach and French *(this volume)*.

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[1] A recent U/Pb (zircon) date from the Devils Room Granite indicates a Lower Devonian Age (P. Erdmer, personal communications, 1986.

[2] Fire assay preconcentration with neutron activation analysis by Chemex Labs Ltd., Vancouver.

Unknown Brook, Browning, and Simms Ridge Prospects - Possible Silurian Epithermal-Fumarolic Activity

A massive pyrophyllite zone up to 15 m thick is developed at Unknown Brook (Snelgrove, 1935) and is associated with pervasively altered zones of sericite, chlorite and carbonate-magnetite. Quartz-carbonate veins are present in the pyrophyllite and sericite-altered areas, and quartz-feldspar-pyrite veins occur in the relatively unaltered silicic tuffs which host the alteration zone. The silicic volcanic rocks are interpreted as forming the lowest unit of the Sops Arm Group (Smyth and Schillereff, 1982).

At the Browning Prospect, located in the Simms Ridge Formation, the bottom part of the exposed section consists of massive siderite beds up to 1 m thick, which are commonly profusely spotted with green mica. These are overlain by a thin chlorite-schist unit (which may represent a shallow thrust zone) and which is in turn overlain by a thicker pyrophyllite-sericite alteration zone. Quartz-carbonate veins are common and locally contain abundant pyrite, chalcopyrite, and minor gold (Snelgrove, 1935). Lenses of laminated, impure chert, up to 15 cm thick and 5 m long, and containing fine grained disseminated pyrite and galena as well as fracture-controlled pyrite and galena, occur above the carbonate beds. Chips of this rock were analysed and gave a value of 65 ppb Au. Siderite cubes in the overlying shales of the Simms Ridge Formation become more abundant toward the areas of mineralization. Plate 1 illustrates a small alteration zone about 200 m upstream from the Browning Prospect.

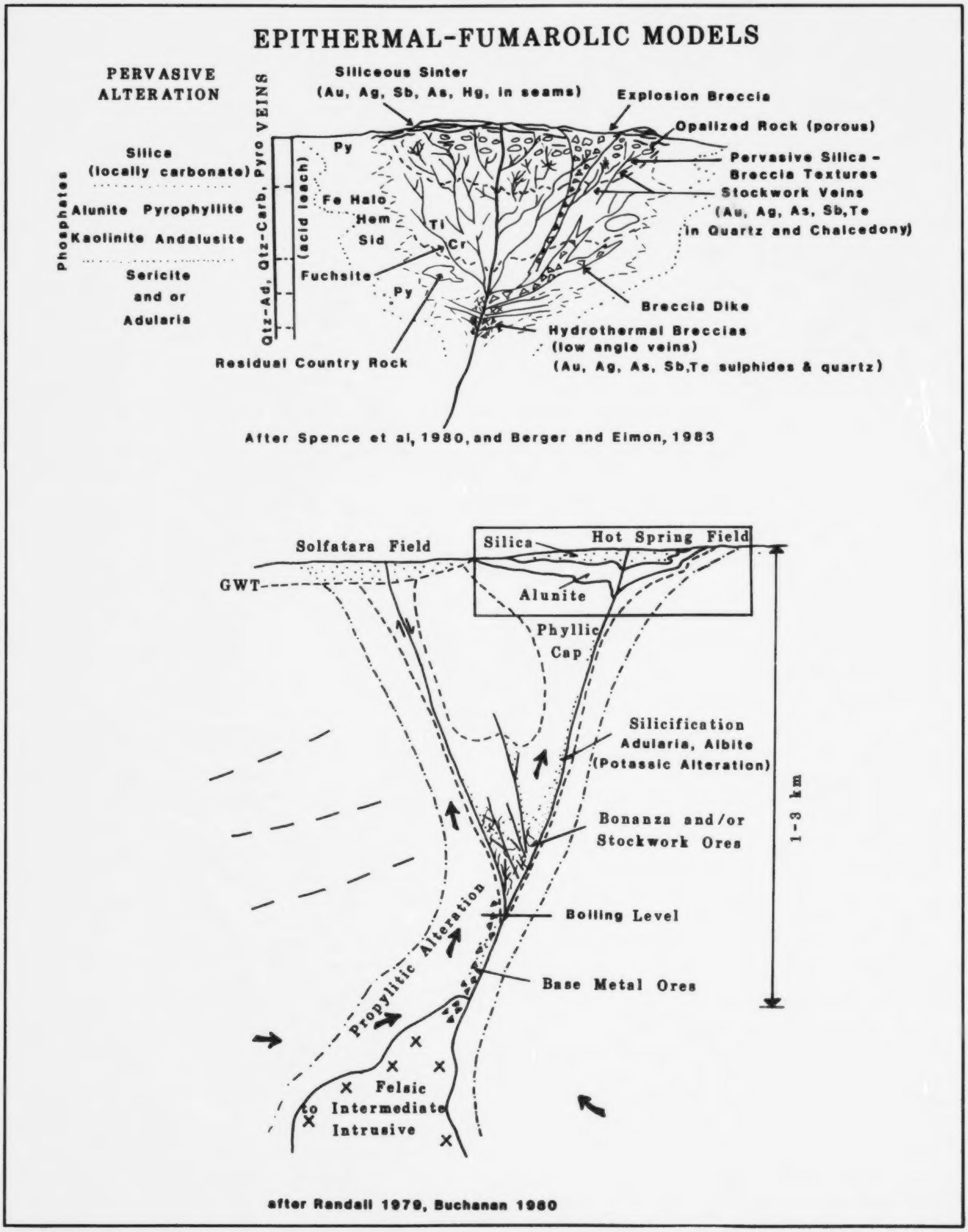
Plate 1: *Pyrophyllite(?) alteration (white), adjacent to a fracture in shales which contain thin, resistant, carbonate beds, Browning Prospect.*

Minor galena and pyrite occur in the Simms Ridge Formation at Simms Ridge and are hosted by quartz-carbonate veins, and minor disseminated pyrite occurs in tuffs which have been subjected to intense carbonate alteration. Siderite grains (Plate 2) in the overlying shales increase in abundance toward this prospect. Gold values are reported from this area by Snelgrove (1935).

Plate 2: *Siderite spots (cubes) on surface of shale from the Simms Ridge area.*

The Unknown Brook, Browning and Simms Ridge prospects, and their host rocks, exhibit extensive and intense alteration features over a strike length of 4 to 5 km. They also demonstrate elements of the classic epithermal-fumarolic hostsprings model (Spence *et al.*, 1980; Buchanan, 1981; Berger and Eimon, 1983). This idealized model (Figure 3) suggests that a unique unidirectional set of alteration assemblages are developed as a result of acid leaching at sites of meteoric fluid discharge, particularly in terrestrial silicic volcanic terranes. The meteoric systems are established in response to high level magmatic activity, which is commonly associated with caldera environments and/or major lineaments. The dominant alteration consists of pervasive cryptocrystalline silica (locally sinter) overlying high-alumina clay minerals, which in turn overlies sericite-rich rocks, and the entire system may be surrounded by an extensive zone of propylitic alteration (Figure 3). Gold is thought to be precipitated by boiling of the fluids, a phenomenon controlled by pressure, which is controlled by porosity.

These are dynamic and changing environments, and gold can be precipitated at any level. The formation of high-


EPITHERMAL-FUMAROLIC MODELS
PERVASIVE ALTERATION
Silica (locally carbonate)
Alunite Pyrophyllite
Kaolinite Andalusite
Sericite and or Adularia
Phosphates
Qtz-Ad, Qtz-Carb, Pyro VEINS
(acid leach)
Siliceous Sinter (Au, Ag, Sb, As, Hg, in seams)
Explosion Breccia
Opalized Rock (porous)
Pervasive Silica - Breccia Textures
Stockwork Veins (Au, Ag, As, Sb, Te in Quartz and Chalcedony)
Py
Fe Halo
Hem
Sid
Ti
Cr
Fuchsite
Py
Breccia Dike
Hydrothermal Breccias (low angle veins) (Au, Ag, As, Sb, Te sulphides & quartz)
Residual Country Rock
Solfatara Field
Silica
Hot Spring Field
GWT
Alunite
Phyllic Cap
Silicification Adularia, Albite (Potassic Alteration)
Bonanza and/or Stockwork Ores
1-3 km
Boiling Level
Propylitic Alteration
Base Metal Ores
Felsic to Intermediate Intrusive

After Spence et al, 1980, and Berger and Eimon, 1983

after Randall 1979, Buchanan 1980

Figure 3: *Idealized alteration and structural features in epithermal-fumarolic systems. Sources of models are listed on diagrams. Note that these models are applicable to all of the areas with cross hatching shown on Figure 1 (including the La Poile Group on the southwest coast).*

alumina clay minerals is thought to be unique to acid-leach environments which only occur at or near surface. Carbonate-dominated systems may form in sediment-dominated basins, and carbonate terracing may develop (C. O'Driscoll, personal communication, 1985). These latter systems are not well documented.

The classic alteration assemblages occur at Unknown Brook and elements of the alteration package are present at the Browning Prospect. In the latter area, carbonate deposition at the base of the Simms Ridge Formation may have caused variations from the idealized patterns, expressed by the presence of siderite.

The distribution of siderite cubes with respect to known mineralization implies that they are related to hydrothermal alteration systems, which developed during and after deposition of the shales. These systems may also have introduced iron into the shales, a feature which may be equated with the extensive propylitic alteration halos that surround epithermal systems (Buchanan, 1981; Figure 3A). The Simms Ridge Formation is characterized by the presence of siderite cubes (Lock, 1969; Smyth and Schillereff, 1982), which may indicate that epithermal-fumarolic systems were active throughout the entire formation.

The presence of laminated, cherty, mineralized lenses at the Browning Prospect suggests that the mineralizing event was in part contemporaneous with deposition of the Simms Ridge Formation. Fossiliferous limestone beds occur about 200 m upstream and along strike from the Browning Prospect; these contain minor disseminated galena. The fossiliferous beds are probably of Silurian age (Lock, 1969), suggesting that the chert beds and hence the epithermal-fumarolic systems are also of Silurian age.

Plutonic rocks are abundant, and fine grained intrusive porphyries form an integral part of the volcanic sequence in the Sops Arm area. Possible association of mineralization and alteration with the Gull Lake Intrusive Suite has been suggested by previous authors (eg., Smyth and Schillereff, 1982). The age of the Gull Pond Granite is currently under investigation.[1]

Corner Brook and Park Prospects

The Corner Brook Prospect consists of anastomosing, quartz-filled, gash veins in a rhyolite porphyry. These veins contain minor pyrite, galena, and chalcopyrite, and minor gold values have been reported (Snelgrove, 1935).

A similar style of mineralization is present approximately 500 m south of the Main River in a north-facing quarry wall over a 30 m^2 area. Mineralization consists of stringer pyrite, minor chalcocite, and minor chalcopyrite in narrow quartz veins cutting rhyolitic tuff. Malachite staining also occurs locally. Chips from this outcrop were analyzed and gave a value of 120 ppb Au; the estimated copper content is less the 0.1 percent. A 30 cm wide vertical quartz vein, trending 020, outcrops for 20 m in an east-facing roadcut approximately 150 m south of the copper showing. Analyses of two chip samples from the vein returned values of 203 and 541 ppb Au. A second parallel vein with a strike length of 2 to 3 m occurs about 25 m west of the road; minor pyrite and galena are present, and a sample of chips from the vein gave an analysis of 2730 ppb Au. The Park Prospect is a new name proposed for the collective showings in this area.

Minor pink-feldspar alteration is associated with the gash vein style of mineralization and sericite is present locally. These veins may represent deeper levels of mineralization (Figure 3; Buchanan, 1981) than the Unknown Brook, Browning and Simms Ridge prospects.

Other Mineralization and Alteration

A small deformed pyrophyllite alteration zone is present at UTM grid reference 044098 in the Hampden map area, (12H/10). A 40 cm wide chloritic shear zone containing minor quartz veins, and a 40 cm wide quartz vein containing minor galena, pyrite and chalcopyrite occur at UTM grid reference 045096, NTS 12H/10. Both of these are in west-facing roadcuts on the main road south of Sops Arm. Chips from the shear zone and the quartz vein gave values of 992 and 880 ppb Au respectively.

Carbonate rocks (Unit 1a of Smyth and Schillereff, 1981, 1982; UTM grid reference 038832, NTS 12H/10) at the southeast margin of the Gull Pond Intrusive Suite contain hematite veins, asbestiform minerals and tremolite(?), which represent a skarn mineralogy. Two samples submitted by the author for multi-element scans did not return anomalous values for minerals of economic interest.

The quartz-magnesite-talc-fuchsite rocks reported by Smyth and Schillereff (1981, 1982; Unit 14) near Jackson's Arm probably represent severely deformed and altered ultramafic rocks. They are associated with rocks of oceanic affinity which occur in a narrow, linear, fault-bounded belt in the map area (Williams, 1977; Smyth and Schillereff, 1982). These rocks and associated faults may form part of the Doucers Valley Fault System (Lock, 1969) and may have a fundamental control on regional mineralization (for further discussion, see Tuach and French, *this volume).* Two large boulders (2 to 3 m across) of virginite (Newfoundland's mariposite) were noted by V. French (personal communication, 1985) along the trace of this lineament between Jackson's Arm and Sops Arm. Bulk chip samples were collected by the author across three lenses of the quartz-magnesite rock at its northern end near Jackson's Arm. The central lens returned an analysis of 24 ppb Au across 10 m. The other lenses had values of less than 1 ppb. Comparable alteration and tectonic features are present in the Mother Lode district of California (Albers, 1980; Landefeld, 1985).

Massive, dark grey colored, brown weathering rocks exposed in roadcuts approximately 1 km south of Main River Park contain a large volume of carbonate (ankerite?). A sample of chips from the northern exposure gave an analysis of 521 ppb Au.

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[1] A recent U/Pb (zircon) date of 390 Ma has been obtained by P. Erdmer (personal communication, 1986)

SOUTHWEST COAST

Introduction

Lithogeochemical sampling and reconnaissance work were performed in the area mapped by Brown, (1976, 1977), and Chorlton (1978, 1980a, b, 1983), on Newfoundland's southwest coast. Figure 4 is a geological summary of their work taken from the mineral occurrence compilation map (Newfoundland Department of Mines and Energy Map 84-61; and from Sean O'Brien, personal communication, 1985). The reader is referred to these authors for details of geology and nomenclature. Most significant prospects on the southwest coast were visited during the summer. The prospects in the La Poile Group are not discussed in this paper, however the model presented in Figure 3 may be applicable.

Granitoid rocks which are spatially and possibly genetically associated with significant mineralization, and from which no previous chemical data are available, were sampled in the southwest coast area. The Ordovician(?) Roti Granite was sampled in the La Poile (110/9) map area (Roti west[1]) and in the Peter Snout (11P/13) map area (Roti east[1]). The Devonian Chetwynd Granite was sampled in the La Poile River (110/16) and Peter Snout map areas, and the Silurian(?) Ironbound Hills, Peter Snout, and Rose Blanche east[2] plutons were sampled in the La Poile River and Peter Snout map areas.

A relatively large number of analyses are available from the Silurian(?) Hawks Nest Pond Porphyry and the Ordovician(?) Baggs Hill Granite (Chorlton, 1980b). Analyses from the Devonian Windowglass Hill Granite and the Devonian-Carboniferous Strawberry and Isle Aux Morts Brook granites are reported by Wilton (1984). A compilation of all geochemical data on granitoid rocks may be of interest to companies exploring for gold in this area.

Granophile Mineralization in the Cape Ray Area

Minor molybdenite is present as disseminations in a small (1 m long) aplite vein adjacent to the northwestern margin of the Isle Aux Morts Brook Granite (UTM grid reference 496865, NTS 110/11; Wilton, 1984). Minor disseminated molybdenite also occurs in quartz veins (10 cm wide) within the granite at this locality. These veins are rare, widely spaced, and contain minor pyrite and possibly minor galena. Two, subvertical, tuffisite-breccia veins, up to 1 m wide and cemented by massive to banded cryptocrystalline silica, are exposed over a strike length of 10 m in a stream bed. The host granite is medium grained, orange, miarolitic, and alkali-feldspar bearing, and is typical of Late Devonian-Carboniferous posttectonic plutons of anorogenic affinity in the area (Wilton, 1985a). The contact between the granite and a possible roof pendant of retrogressed Port Aux Basques Gneiss is exposed at this locality (Wilton, 1984).

Fluorite is reported by Wilton (1984) at the northeastern margin of the Strawberry Granite (UTM grid reference 563918, NTS 110/15). It occurs in fractures and as matrix to well developed gas breccias which are dominantly cemented by massive and chalcedonic quartz. The breccia extends over a length of 200 m in Isle Aux Morts Brook. Minor disseminated molybdenite is also reported in fine grained granite at this locality (Wilton, 1984). The Strawberry Granite shows many similarities to the Isle Aux Morts Brook Granite.

Posttectonic, anorogenic, alkali-feldspar, biotite granites ('A'-type plutons, Collins *et al.*, 1982) are commonly associated with major mineral deposits (e.g., Climax, Colorado, White *et al.*, 1981; Mount Pleasant, New Brunswick, Taylor *et al.*, 1985) and host the Ackley Granite molybdenite and tin deposits in Newfoundland (Tuach *et al.*, 1986). The gas breccias, miarolitic cavities, and minor mineralization in the Isle Aux Morts Brook and the Strawberry granites indicate some potential for significant granitoid-related mineralization in these plutons.

Plutons with Anomalous Radioactivity

The Ironbound Hills Syenite and the Peter Snout Granite are massive, essentially posttectonic plutons (Dunsworth, 1981; Chorlton, 1980a), which exhibit high radioactivity from 3 to 5 times normal background (up to 1000 cps on an EDA GRS 500 spectrometer). Uranium mineralization in the Baggs Hill Granite and in the Bay Du Nord Group (Wells, 1981: O'Brien and Tomlin, 1985) may be genetically related to these plutons.

Precious Metals Associated with the Cape Ray Tonalite Complex

The Cape Ray Tonalite Complex occurs at the southern extremity of the Long Range ultramafic-mafic-tonalite-granite terrane shown on Figure 4, (Wilton, 1984).

Minor galena is present in the Bear Cove Showing at Red Rocks Point (UTM grid reference 263817, NTS 110/11), and occurs as several isolated oval-shaped (10 cm x 5 cm) aggregates. This mineralization occurs in a narrow north-northeast trending quartz vein (30 cm wide) at the margin of posttectonic porphyry dikes. The dikes cut foliated megacrystic granites of the Cape Ray Tonalite Complex. A sample of porphyry dike with minor disseminated pyrite, taken adjacent to the vein, returned analyses of 77 ppm Pb and 8 ppm Ag (D. Wilton, personal communication, 1985).

Two narrow (2 to 8 cm) quartz veins containing chalcopyrite and pyrite comprise the Stackhouse Showing (Wilton, 1984),which occurs on the shoreline approximately 200 m north of the lighthouse at Cape Ray (UTM grid reference 265706, NTS 110/11). The veins dip at 10 to 15 degrees to the southwest and cut foliated megacrystic granite

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[1] The two outcrop areas of the Roti Granite as mapped by Chorlton (1978, 1980a) are separated by a distance of 25 km. They are informally called the Roti east and Roti west plutons for identification purposes.

[2] The Eastern exposures of the Rose Blanche Granite (Chorlton, 1980a; Dunsworth, 1981) are informally named the Rose Blanche east Granite.

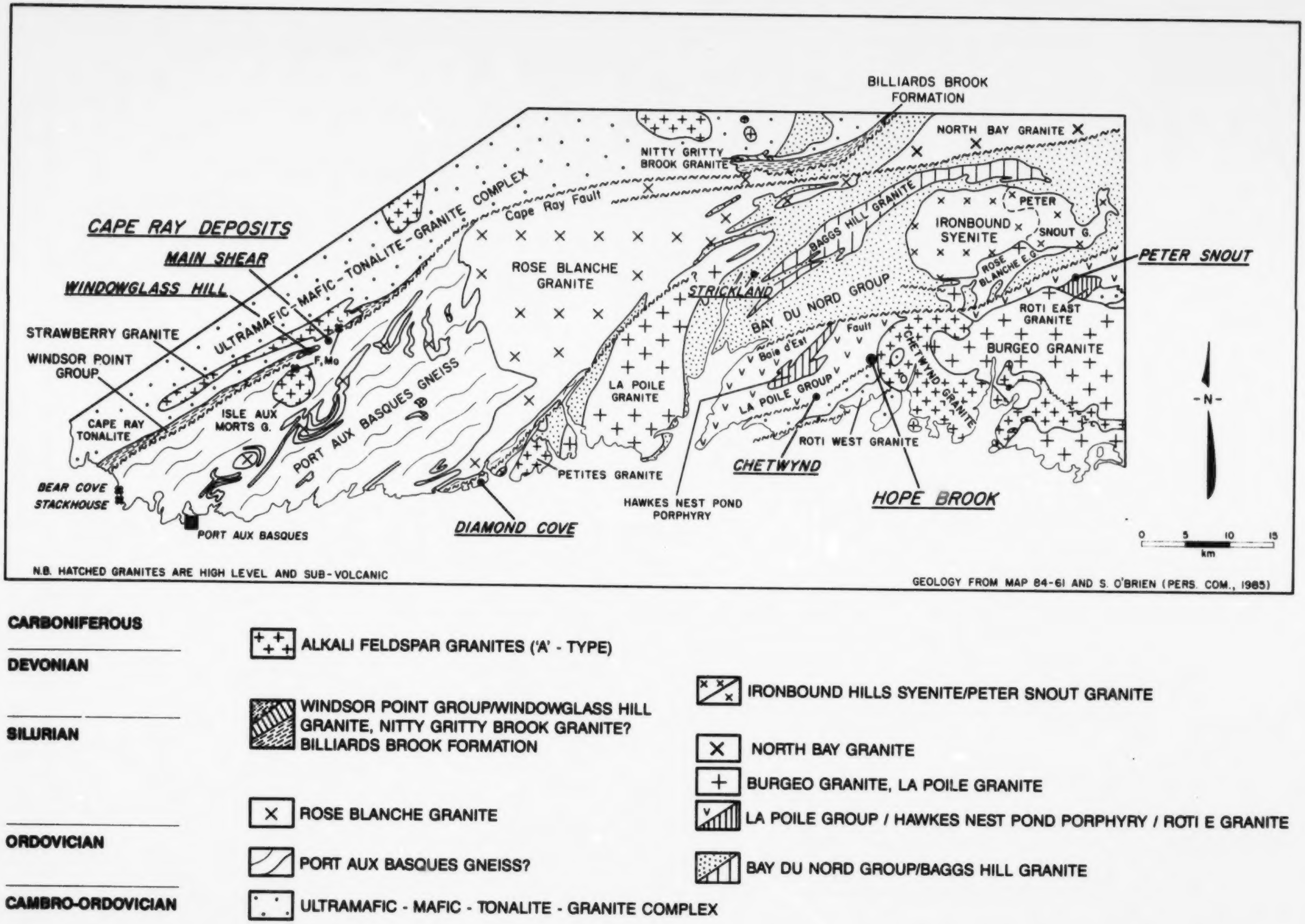
BILLIARDS BROOK FORMATION
NORTH BAY GRANITE
NITTY GRITTY BROOK GRANITE
Cape Ray Fault
ULTRAMAFIC - MAFIC - TONALITE - GRANITE COMPLEX
CAPE RAY DEPOSITS
MAIN SHEAR
WINDOWGLASS HILL
STRAWBERRY GRANITE
WINDSOR POINT GROUP
CAPE RAY TONALITE
F, Mo
ISLE AUX MORTS G.
PORT AUX BASQUES GNEISS
BEAR COVE
STACKHOUSE
PORT AUX BASQUES
ROSE BLANCHE GRANITE
LA POILE GRANITE
PETITES GRANITE
DIAMOND COVE
HAWKES NEST POND PORPHYRY
STRICKLAND
BAGGS HILL GRANITE
BAY DU NORD GROUP
Baie d'Est
Fault
LA POILE GROUP
ROTI WEST GRANITE
CHETWYND
CHETWYND GRANITE
HOPE BROOK
IRONBOUND SYENITE
PETER
SNOUT G.
ROSE BLANCHE E.G.
PETER SNOUT
ROTI EAST GRANITE
BURGEO GRANITE
- N -
0
5
10
15
km
N.B. HATCHED GRANITES ARE HIGH LEVEL AND SUB-VOLCANIC
GEOLOGY FROM MAP 84-61 AND S. O'BRIEN (PERS. COM., 1985)
CARBONIFEROUS
DEVONIAN
SILURIAN
ORDOVICIAN
CAMBRO-ORDOVICIAN
ALKALI FELDSPAR GRANITES ('A' - TYPE)
WINDSOR POINT GROUP/WINDOWGLASS HILL GRANITE, NITTY GRITTY BROOK GRANITE? BILLIARDS BROOK FORMATION
ROSE BLANCHE GRANITE
PORT AUX BASQUES GNEISS?
ULTRAMAFIC - MAFIC - TONALITE - GRANITE COMPLEX
IRONBOUND HILLS SYENITE/PETER SNOUT GRANITE
NORTH BAY GRANITE
BURGEO GRANITE, LA POILE GRANITE
LA POILE GROUP / HAWKES NEST POND PORPHYRY / ROTI E GRANITE
BAY DU NORD GROUP/BAGGS HILL GRANITE

Figure 4: *Summary of geology and location of selected mineral deposits on the southwest coast of Newfoundland. After Brown (1976, 1977), Chorlton (1978, 1980a, b, 1983) and S. O'Brien (personal communication, 1985).*

of the Cape Ray Tonalite Complex. Separation between the veins is approximately 15 cm, and they are connected by vertical, relatively unmineralized, quartz veins; the veins outcrop over an area of approximately 25 m^2. Chalcopyrite may be either concentrated along the vein margin or may occur as large pods in the vein. Wilton (1984) reported an assay value of 7.7% Cu, 1.03 ppm Au, and 69.9 ppm Ag from a grab sample. He also noted the presence of minor chalcocite and supergene covellite in polished thin section (D. Wilton, personal communication, 1985).

Both the Stackhouse and Bear Cove veins post date the penetrative deformation of the host rocks, and may be genetically related to magmatism and/or tectonism along the Cape Ray Fault Zone.

Major Gold Prospects in the Cape Ray Fault Zone

The Main Shear quartz-gold lodes (Plate 3) and the vein and stockwork prospects in the Windowglass Hill Granite (Plate 4) have been described by Wilton (1984, 1985b). A schematic drawing illustrating local geological features is presented in Figure 5. Wilton's models assume that the Devonian Windowglass Hill Granite was generated in the Cape Ray Fault Zone and suggest that the granite is a source for gold mineralization in this area. Graphitic host rocks, which are interpreted by Wilton to be part of the Devonian Windsor Point Group, are also interpreted by him to have formed a physiochemical trap which localized deposition of quartz and gold as the Main Shear deposits. Similar settings may occur elsewhere along the Cape Ray Fault zone, eg., in the vicinity of the Nitty Gritty Brook Granite.

Portions of the favourable graphitic zone in the vicinity of the Main Shear deposits have not been adequately tested by drilling. There is room to improve on reserve tonnage in this area.

Plate 3: *Main Shear gold-quartz lode (white) in a laminated and bedded, graphitic, sedimentary rock.*

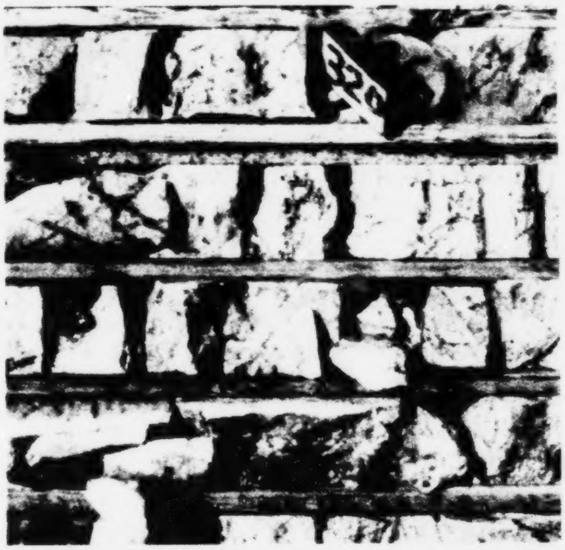

Plate 4: *Stockwork quartz veins in the Windowglass Hill Granite.*

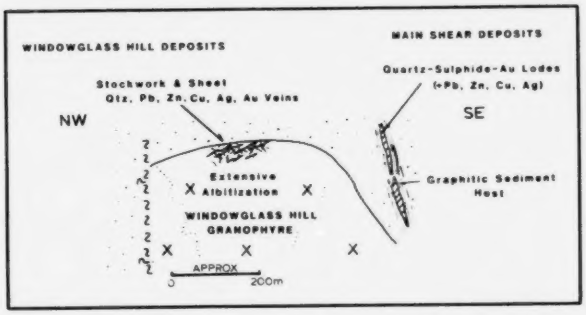
WINDOWGLASS HILL DEPOSITS
MAIN SHEAR DEPOSITS
Stockwork & Sheet Qtz, Pb, Zn, Cu, Ag, Au Veins
Quartz-Sulphide-Au Lodes (+Pb, Zn, Cu, Ag)
NW
SE
Extensive Albitization
WINDOWGLASS HILL GRANOPHYRE
Graphitic Sediment Host
APPROX
0
200m

Figure 5: *Schematic diagram of geological and mineralization features at the Cape Ray gold deposits (after Wilton, 1984).*

Gold Potential in the Port Aux Basques Gneiss and the Bay Du Nord Group

The host to the Main Shear deposits is a penetratively deformed sequence of bedded to laminated mafic tuff, silicic tuff and pyroclastic rocks, mafic volcanogenic sedimentary rocks, and bedded and laminated graphitic shale (Plate 3). Rocks in drill core, logged as Port Aux Basques Gneiss, which are of amphibolite facies metamorphic grade, are comparable in lithology to the rocks logged as Devonian Windsor Point Group; a boundary cannot be readily identified between these two units in the drill core. It seems probable that the host rocks to the Main Shear deposits are part of a typical greenschist facies, sedimentary/volcanic, Ordovician assemblage which is correlative with the Port Aux Basques Gneiss, and possibly with the Bay Du Nord Group (see Chorlton, 1983).

This latter observation is important with respect to the exploration potential for lode-gold deposits in southwestern Newfoundland since it implies that formations other than the Devonian sequences, which are confined to the Cape Ray Fault zone, may localize gold deposition. Graphitic schists are present throughout the Bay Du Nord Group and may be present in the Port Aux Basques Gneiss. Crosscutting granites of various ages are ubiquitous in both of these units. In addition, there are numerous pronounced lineaments on the southwest coast of Newfoundland which may be of geological importance as loci of precious metal deposition.

The large quartz vein at Diamond Cove (Plate 5) has abundant graphite-coated partings and minor associated graphitic schist. It is reported to be auriferous and contains minor base metal mineralization (Snelgrove, 1935; Howse and Collins, 1984). In addition, it lies at or near a relatively large lineament which is depicted on Figure 3, and is spatially associated with the Rose Blanche Granite. The similarity in setting of the auriferous Diamond Cove vein and the Main Shear lode-gold deposits lends some support to the arguement that lode-gold deposits may be more widespread than previously recognized, and may suggest that further evaluation of the Diamond Cove area for gold is warranted.

Plate 5: *Diamond Cove Quartz Vein with graphitic sedimentary bands.*

The Windowglass Hill Granite is a high level pluton characterized by high Na_2O/K_2O ratios (see Appendix 1; Wilton, 1985b), which together with the stockwork and sheet quartz veins (Plate 4), and high Pb-Zn-Cu base metal values, imply the presence of a hydrothermal alteration zone (albitized area in Figure 5). Wilton (1984, 1985b) has argued that the Windowglass Hill Granite is a source of gold mineralization in the Cape Ray area. Analytical data presented by Chorlton (1980b; and Table 1) for the Baggs Hill Granite show that 11 out of 32 samples have strong sodium enrichment (one sample exhibits strong potassium enrichment and has been excluded from Table 1; compare to Wynne and Strong, 1984). The Baggs Hill Granite is a large, high level, granophyric and miarolitic subvolcanic pluton which merges with deformed volcanic pyroclastic rocks of the Bay Du Nord Group (Chorlton, 1980b). Three of the high sodium samples in this granite were collected within 1 km of the Strickland Prospect, while the others are scattered along the length of the granite. These features imply that the Na_2/K_20 ratio may be a powerful, primary, prospecting tool and that the Baggs Hill Granite and adjacent country rocks may have potential for hosting gold deposits.

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Note: Mineral Development Division file numbers are included in square brackets.

APPENDIX 1

Comparisons of Analyses from the Windowglass Hill Granite (Wilton, 1985a) and the Baggs Hill Granite (Chorlton, 1980b)

	Windowglass Hill N = 24		Albitized Baggs Hill N = 11		Relatively Unaltered Baggs Hill N = 20	
	$\bar{x}$	$\bar{s}$	$\bar{x}$	$\bar{s}$	$\bar{x}$	$\bar{s}$
SiO_2(wt%)	77.5	3.2	77.50	2.32	76.52	1.03
TiO_2	0.11	0.09	0.11	0.07	0.12	0.04
Al_2O_3	13.1	5.5	12.3	0.7	12.42	0.55
Fe_2O_3	1.0	0.7	0.48	0.31	1.1	0.4
MnO	0.02	0.01	0.02	0.01	0.02	0.01
MgO	0.16	0.26	0.15	0.11	0.15	0.09
CaO	0.71	0.85	0.69	0.46	0.30	0.13
Na_2O	5.6	3.1	5.44	0.64	4.10	0.34
K_2O	1.7	2.1	1.22	1.08	3.92	0.31
RO_5	0.02	0.03	0.01	0.01	0.03	0.02
V (ppm)	11	18	6	5	7	5
Cr	3	4	4	2	4	4
Ni	8	10	7	8	14	10
Cu	163	419	4	2	6	13
Zn	230	825	35	22	41	26
Ga	25	19	23	3	19	5
As	22	22				
Rb	46	66	47	44	130	60
Sr	118	142	57	14	63	41
Y	100	53	84	32	71	35
Zr	266	91	221	58	191	64
Nb	30	13	18	5	23	10
Ag*	2381	5639				
Ba	227	306	232	194	493	172
Au*	177	729				
Pb	452	977	11	6	18	11
La	19	38	44	14	34	26
Ce	76	61	87	31	83	28
Th	21	10				
U	4	4				

* These analyses reported as ppb.

$\bar{x}$ Mean

$\bar{s}$ One standard deviation

Current Research (1986) Newfoundland Department of Mines and Energy,
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GOLD MINERALIZATION OF POSSIBLE LATE PRECAMBRIAN AGE IN THE JACKSON'S ARM AREA (12H/15), WHITE BAY, NEWFOUNDLAND

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and

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INTRODUCTION

Gold mineralization was discovered in granitic rocks of Late Grenville age, located to the west of Jackson's Arm (Figure 1), by prospector Clyde Childs of York Harbour in the fall of 1983. The mineralization occurs in a rusty pyritiferous 'shear zone' that was exposed during construction of the access road to the Cat Arm hydroelectric project. Subsequently, the area surrounding the discovery was staked by Labrador Mining and Exploration (Childs' employers), and additional prospecting has improved the potential of the area (French, 1985).

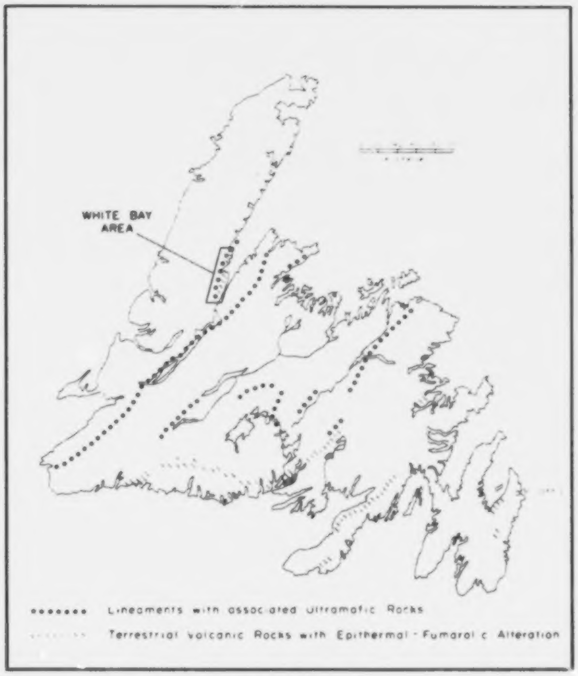
WHITE BAY AREA
Lineaments with associated Ultramafic Rocks
Terrestrial Volcanic Rocks with Epithermal - Fumarolic Alteration

Figure 1: *Location of White Bay area in western Newfoundland.*

The objectives of this report are to outline general geological information, and to present some observations and thoughts on the mineralizing system in the Jackson's Arm area. These may assist in prospecting throughout the Grenville Province and in similar environments elsewhere. It is stressed that the ideas presented are based primarily on field work, in an area of limited exposure, and are subject to considerable modification. Detailed assays, and geological and structural information are currently confidential.

The area of interest is heavily forested with less than 5 percent outcrop, except along the Cat Arm road where there is approximately 95 percent exposure in roadcuts. The topography is rugged (Plate 1), making traversing slow and difficult.

Plate 1: *Topography and vegetation in the vicinity of gold prospects in the Jackson's Arm area.*

This project is a contribution to the Canada-Newfoundland Mineral Development Agreement, 1984-1989

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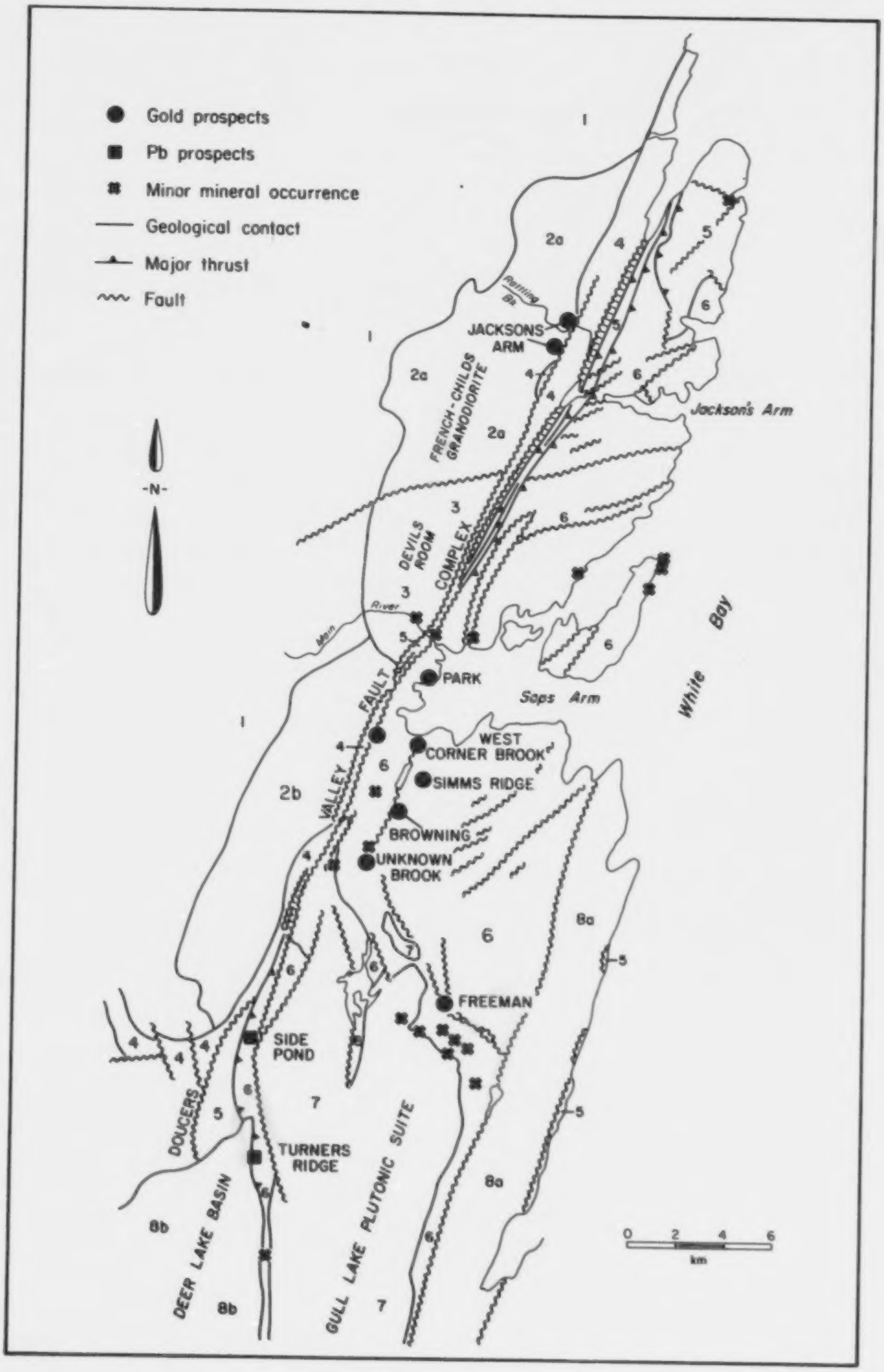
● Gold prospects
■ Pb prospects
✱ Minor mineral occurrence
Geological contact
Major thrust
Fault
-N-
1
2a
2b
3
4
5
6
7
8a
8b
JACKSONS ARM
Jackson's Arm
FRENCH-CHILDS GRANODIORITE
DEVILS ROOM
COMPLEX
Main River
VALLEY FAULT
PARK
Sops Arm
White Bay
WEST CORNER BROOK
SIMMS RIDGE
BROWNING
UNKNOWN BROOK
FREEMAN
SIDE POND
TURNERS RIDGE
DOUCERS
DEER LAKE BASIN
GULL LAKE PLUTONIC SUITE
0 2 4 6
km

Figure 2: *General geology in the western White Bay area, after Smyth and Schillereff (1982) and Erdmer (1986).*

LEGEND

UPPER PALEOZOIC (Basin Fill Sequences and Intrusions)

CARBONIFEROUS

8 8b, Deer Lake Group (Visean);
8A, Anguille Group (Tournasian)

DEVONIAN OR EARLIER?

7 Gull Lake Intrusive Suite

SILURIAN

6 Sops Arm Group

LOWER PALEOZOIC ALLOCHTHON

CAMBRIAN - MIDDLE ORDOVICIAN

5 Southern White Bay Allochthon—partially ophiolitic; mélange containing ultramafic blocks is cross-hatched.

LOWER PALEOZOIC AUTOCHTHON (platform)

4 Coney Arm Group

PRECAMBRIAN (Grenville basement)

LATE PROTEROZOIC(?)

3 Devils Room Granite [1]

MID PROTEROZOIC AND EARLIER (>1105 ± 90 Ma)

2 Massive to foliated, feldspar megacrystic, granitoid plutons.
2a: French Childs granodiorite; 2b: granite.

1 Leucocratic gneiss, amphibolite and gabbro.

GENERAL GEOLOGY

A generalized geology map of the Jackson's Arm - Sop's Arm area of White Bay is presented in Figure 2. The Paleozoic geology is summarized from Smyth and Schillereff (1981, 1982) and the distribution of rocks in the Grenvillian inlier is taken from Erdmer (1986). Erdmer has initiated a 1:100,000 scale mapping project in the Long Range Mountains to the west of White Bay, and the reader is referred to his report for a description of the Grenvillian rocks.

The host rock to the gold mineralization is a variably foliated, coarse grained, feldspar megacrystic granodiorite (Plate 2), informally known as the French-Childs granodiorite. This pluton is one of several in the Precambrian Long Range inlier, and has intruded Proterozoic leucocratic gneiss and foliated diorite after the deformational and metamorphic peak of the Grenvillian Orogeny (Bostock, 1983; Erdmer, 1986). Foliated plutons in the western and northern Long Range Mountains that are comparable to the French-Childs granodiorite have a Rb-Sr age of 1105 ± 90 Ma (Pringle *et al.*, 1971; recalculated with $\lambda = 1.42$). Erdmer (personal communication, 1986) has obtained zircon ages of 1020 Ma from the French-Childs granodiorite and from similar plutons to the west. The granodiorite is nonconformably overlain by basal Eocambrian quartzite (Plate 3) and minor conglomerate of the Beaver Brook Formation (Lock, 1969; Smyth and Schillereff, 1982). These rocks were correlated with the the Bradore Formation of the Labrador Group, which outcrops along the western and northern boundaries of the Long Range inlier.

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[1] A recent U-Pb (zircon) date from the Devils Room Granite indicates a Lower Devonian age (P. Erdmer, personal communication, 1986).

Plate 2: *The French-Childs grandiorite.*

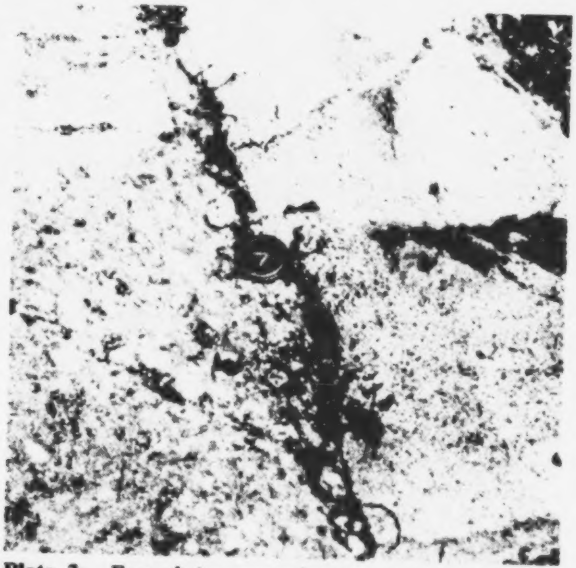

Plate 3: *Eocambrian unconformity showing the Beaver Brook Formation (right) overlying foliated grandiorite.*

The Long Range dikes (Bostock, 1983; Erdmer, 1984) are conspicuous in the gneissic terrane of the area. These trend north-northeast and are strongly retrogressed to greenschist facies assemblages along the eastern side of the Long Range Mountains (Erdmer 1984,1986). Large dikes have not been observed in the French-Childs granodiorite, but there are small retrogressed and boudinaged diabase and diorite bodies which may be related to these dikes. Stukas and Reynolds (1974) obtained an ^{40}Ar/^{39}Ar age from the dikes of 614 ± 10 Ma (recalculated using the decay constants recommended by Steiger and Jager, 1977), which they considered to represent the approximate age of intrusion.

The Devils Room Granite is a triangular-shaped, undeformed, zoned pluton (Smyth and Schillereff, 1982; Dunford, 1984) which is in fault contact with the French-Childs granodiorite (Erdmer, 1986). It intrudes Grenvillian gneiss on its western boundary, and is in fault contact with Cambro-Ordovician rocks along its eastern margin. A zircon age of 390 Ma has recently been obtained by P. Erdmer (personal communication, 1986) which supports earlier suggestions that the pluton is Devonian in age and related to the Gull Lake Intrusive Suite (Lock, 1969). Smyth and Schillereff (1981), and Dunford (1984), correlated the Devils Room Granite with comparable posttectonic granites in the northern Long Range inlier that were assigned to the Precambrian (Bostock, 1983). Long Range dikes are not observed in the Devils Room Granite, a feature which supports a Paleozoic age for the pluton.

Several, relatively unmetamorphosed, 'late' diabase dikes, generally less than 1 m wide, trend east-northeast and cut the French-Childs pluton and its contained alteration and mineralization. Dikes with comparable appearance and attitude intrude the Cambro-Ordovician carbonate succession in Little Coney Arm (Plate 4). These dikes appear to postdate the Taconic Orogeny, and may provide a younger age limit for the mineralizing event in the French-Childs granodiorite.

Plate 4: *Diabase dikes cutting Cambro-Ordovician limestone sequences of the Coney Arm Group in Great Coney Arm.*

Grenvillian rocks in the western and central parts of the Long Range inlier are at upper amphibolite to granulite facies metamorphic grade. Most of the rocks in the western margin of the inlier have been retrogressed to greenschist facies assemblages, including the French-Childs granodiorite and the Long Range dikes. More than one period of retrogression may have occurred (Bostock, 1983), and these may be attributed to overthrusting and westward movement of the ophiolite klippe in western Newfoundland during the Taconic Orogeny, prior to uplift of the Long Range Mountains (Bostock, 1983; Erdmer, 1986).

Structure in the Long Range inlier was described by Erdmer (1986). Several prominent linear trends are evident at 030, 060, and 155 degrees and reflect post-Grenville fracturing and possible fault movement in the Long Range inlier. The major structures in the Paleozoic rocks to the east of the Long Range inlier trend north-northeast and parallel a major lineament defined by the Doucer's Valley Fault Complex (Lock, 1969; 1972), and by intensely deformed mafic rocks of probable oceanic affinity (Williams, 1977).

Rock Types

The following descriptions are confined to rocks and mappable units which may be related to the gold mineralization in the French-Childs granodiorite.

The French-Childs granodiorite. This pluton consists predominantly of a grandiorite phase, and a minor alkali-feldspar granite phase.

Grandiorite phase

This phase is a variably foliated, coarse grained, feldspar megacrystic, biotite granodiorite which intrudes Grenvillian leucocratic gneiss and diorite. Its western boundary in the Jackson's Arm area is a complex zone up to 1 km wide, consisting of granodiorite and country rocks. The granodiorite is unconformably overlain by Eocambrian quartzite on its eastern boundary. The pluton outline on Figure 1 was defined by Erdmer (1986). Xenoliths and particularly resorbed xenoliths of leucocratic gneiss, felsite, diorite and amphibolite are common, and biotite-rich schlieren are ubiquitous. Felsic xenoliths are generally small (less than 1 m across), in contrast to the mafic xenoliths (up to 50 m across). Deformed and boudinaged, amphibolitized and chloritized, diabase and diorite bodies may be partly derived from Long Range dikes. Small, foliated, pink, fine grained, granitic patches, and local areas of pegmatite, may represent late differentiates formed during magma crystallization.

The granodiorite is mottled, dark green to gray and buff, and contains 35 to 50 percent coarse, buff to gray feldspar crystals (up to 3 cm long) which are variably epidotized. Intense epidotization of megacrysts and groundmass results in a pale green, mottled rock which occurs in zones up to 150 m wide. Feldspar is fractured and broken, and crystal outlines vary from subhedral to ovoid to extremely elongate. The feldspar and the mafic minerals define an augen texture. The matrix consists of quartz, plagioclase, biotite, actinolite, chlorite, and magnetite. Relict clinopyroxene and hornblende and minor sphene were observed in thin section, and up to 10 percent potassic feldspar and minor secondary sericite are present. The pluton ranges from weakly foliated granodiorite to mylonite, recording extreme inhomogeneity of strain during deformation. The attitude of the augen fabric is highly variable throughout the pluton and is seen to 'swirl' in individual outcrops.

Alkali-feldspar granite

This phase of the French-Childs granodiorite is a foliated, orange, generally mafic-mineral free, alkali-feldspar granite. Potassic feldspar has been identified by staining, and by thin section study, and its presence is inferred from high K_2O values in whole rock analyses. It is exposed on the Cat Arm Road for 400 m to the north of Rattling Brook, and for 100 m to the south of Rattling Brook. The contact between the alkali-feldspar granite and the granodiorite to the south is complex, and is marked by either a gradual or sharp color change. Typically, potassic feldspar in the granodiorite phase increases toward the alkali-feldspar granite. Numerous fractures in the granodiorite have selvages and alteration halos of potassic feldspar, and massive, extremely coarse grained feldspars locally occur along fractures in the alkali-feldspar granite (Plate 5). Amphibolite and diorite xenoliths and possible boudinaged dikes occur in the alkali-feldspar granite.

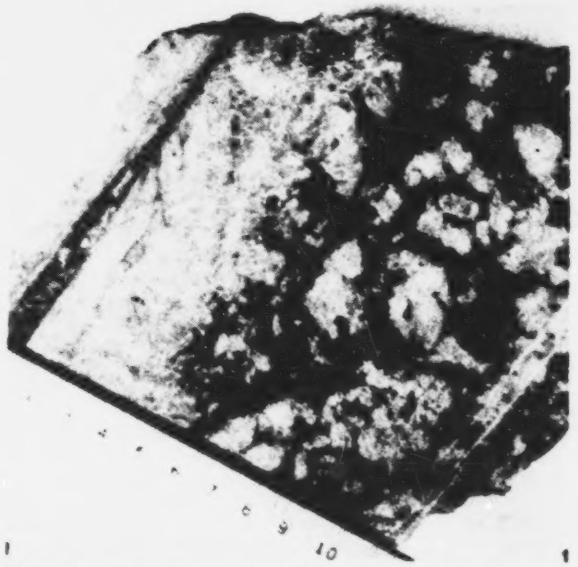

Plate 5: *Massive potassic feldspar crystals bordering cryptocrystalline silica-carbonate-filled fractures in French-Childs grandiorite.*

Foliation and augen textures in the granite are identical to those in the the granodiorite. However, the granite also contains abundant pyrite-quartz-carbonate stockworks, fractures, and gas breccia textures (tuffisite) which postdate the penetrative fabric. Weak, partial sericitization of the alkali feldspar is ubiquitous, and may be related to either hydrothermal alteration phenomena described below or to regional metamorphic retrogression. The alkali-feldspar granite exhibits up to five times greater background radioactivity than the granodiorite.

Quartzite and conglomerate. Eocambrian quartzite of the Beaver Brook Formation unconformably overlies the French-Childs granodiorite along the Cat Arm road (Plate 2). This impure quartzite is characterized by blue quartz grains up to 0.5 cm across and by magnetite-rich laminae. Locally, small pockets of pebble to boulder conglomerate are present and contain well rounded fragments of the French-Childs granodiorite, along with individual plagioclase crystals weathered from the granodiorite. The conglomerate is generally matrix supported, and pebbles of foliated diorite and coarse grained milky quartz are also present.

The quartzite which overlies the alkali-feldspar granite has abundant carbonate and sericite in the matrix, and contains minor pyrite as disseminations and along isolated fractures. No lithic fragments were observed which could be identified as originating from the granite.

Devils Room Granite. This pluton has been described by Smyth and Schillereff (1982), and Dunford (1984). It has a core of medium grained, equigranular, biotite-muscovite granite, surrounded by coarse grained to feldspar megacrystic, biotite granite. Fine grained, massive felsite occurs near the northern boundary of the granite. Fluorite locally occurs in fractures (Smyth and Schillereff, 1982; Dunford, 1984)

Medium to coarse grained, orange to red, equigranular and locally feldspar porphyritic, biotite granite is exposed in new roadcuts on the north bank of the Main River. White, bleached areas up to 50 m long show clay-mineral alteration. Fluorite is present as coatings up to 1 cm thick on fractures, and fluorite-silica cement is present in a 1.5 m wide tuffisite vein. These features represent a late hydrothermal event after granite crystallization. Traces of chalcopyrite and chalcocite are present on isolated fracture surfaces.

The granite is progressively more fractured and brecciated toward its east side. Chlorite-hematite-calcite-manganese coatings are abundant, and slickensides (locally horizontal) are extensively developed. The spatial association of these features with the major lineaments to the east of the granite implies that they developed in response to movement along these lineaments.

Aplite and quartz porphyry. A 2 m outcrop of fine grained, pink aplite occurs in the northern part of the French-Childs granodiorite, and a 1 m outcrop of pink quartz porphyry containing less than 5 percent euhedral quartz phenocrysts (up to 2 mm across) is located approximately 2 km south of the gold showing on the Cat Arm road. Both of these intrusions are unfoliated, and are similar to the aplitic phase in the Devils Room Granite.

A single, 0.3 m thick, subvertical, pink, fine grained aplite vein, trending 060, was observed in the Cambrian(?) limestones just east of the Beaver Brook Formation, and approximately 2 km north of Rattling Brook. This aplite is tentatively correlated with the fine grained, felsic plutons described above.

Late diabase intrusions. Fine grained, dark gray, unmetamorphosed diabase intrusions, up to 1 m wide, trend 060 to 070 and dip from vertical to 70 degrees north (Plate 6). The dikes have well developed chilled margins and coarse grained centres (crystrals up to 1 mm across). These dikes cut the French-Childs granodiorite, the alkali-feldspar granite, and pyritic quartz veins in the granite. Similar dikes with comparable trends intrude the Cambro-Ordovician carbonate sequence exposed in Little Coney Arm (Plate 4).

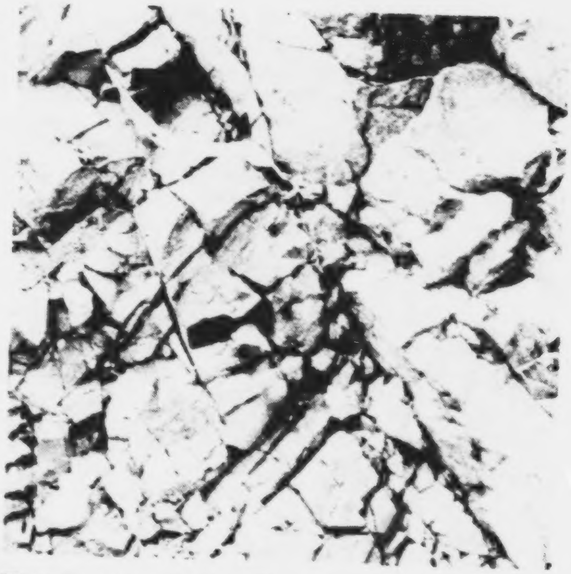

Plate 6: *Late diabase dike intruding potassic feldspar granite.*

ALTERATION AND MINERALIZATION

The well exposed section along the Cat Arm road gives insight into the type of mineralizing system that resulted in gold deposition in the Jackson's Arm area. Structural, textural and well developed alteration phenomena indicate that a moderate to high temperature hydrothermal system overprinted the French-Childs granodiorite after penetrative deformation. Comparable alteration containing minor gold values has been found throughout the French-Childs granodiorite in association with lineaments.

The alteration features observed in the field are subtle and not readily recognizable as being related to a hydrothermal system. Sulfides are present as a minor constituent and gossan zones are rare; hair-line fractures that are carbonate lined form the bulk of the stockwork system, and the potassic zone resembles a deformed alkali-feldspar granite.

Potassic Alteration

A spatial association between potassic feldspar and fractures, and the local presence of coarse grained potassic feldspar as selvages around fractures (Plate 5), were noted in the contact zone between granodiorite and granite to the south of Rattling Brook. This suggests that the alkali-feldspar granite was formed by fluid alteration of granodiorite outward from fractures. The northern exposures of the granite are characterized by abundant stockworks and sheet fractures which are spaced at 1 to 5 cm. These stockworks and sheets contain pyrite, arsenopyrite, quartz, ankerite(?) and sericite, and some contain gold mineralization. Tuffisite is present locally and may have a silicified, carbonated and sulfidized matrix.

The features outlined suggest that the color, mineralogy and composition of the alkali-feldspar granite formed as a result of moderate to high temperature, potassic alteration of a foliated granodiorite. The regionally developed, penetrative foliation which is preserved in the altered granite, is unrelated to the later hydrothermal event. The foliation and the well developed augen structres are cut by stockwork veins and volatile breccias related to the mineralizing system.

Increasing reaction of the wall-rock with hydrothermal fluids, which may relate to fluid composition, temperature, pressure, fluid/rock ratio and fracture density, is thought to have resulted in total replacement of the original feldspar and dissolution of all mafic minerals. Growth of new potassic-feldspar crystals is confined to fracture margins. A late stage of sericite alteration in microfractures radiating from fractures or fluid channels was observed. These fractures commonly contain carbonate, cryptocrystalline silica, fine grained micas and sulfide.

It may be possible that the alkali-feldspar granite represents a separate intrusive phase of the French-Childs granodiorite. However, the transitional boundaries, the spatial relationship to the stockwork system, and the fact that potassic-altered granite is found along several of the pronounced lineaments throughout the French-Childs granodiorite argue for a hydrothermal origin.

Sericite, visible in the intense 'shear' zones and in carbonate- and feldspar-bordered fractures, is a product of the alteration system. Weak, pervasive, partial alteration of potassic feldspar to fine grained sericite is common, and this may be a late stage of development in the alteration system. Alternatively, it may represent a late metamorphic retrogression, correlative with regional retrogression in the eastern Long Range inlier (Bostock, 1983; Erdmer, 1984, 1986).

Carbonate Alteration

Minor Fe-rich carbonate (ankerite?) occurs throughout the alteration system in the Jackson's Arm area, and weathers to a distinct limonitic brown. It is present in silica-sericite-sulfide-rich shear zones, fracture stockworks, and in the matrix to potassic-altered granite and brecciated granite. It is generally very fine grained, but coarsely crystalline carbonate occurs in fractures. Flat-lying fracture sheets, accentuated by limonite staining, are common to the south of the potassic-altered zone around Rattling Brook (Plate 7). Limonite staining related to Fe-carbonate is ubiquitous adjacent to many of the lineaments throughout the Jackson's Arm area.

Gold values are associated with carbonate alteration. However, carbonate alteration does not always contain gold mineralization.

Silica Alteration

Cryptocrystalline silica is found in some of the shear zones and in the matrix to some mineralized tuffisite breccias. Preliminary results from whole rock analyses indicate that the potassic-feldspar alteration is accompanied by an increase in silica content of the rock.

Plate 7: *Parallel fractures, some of which are bordered by limonite staining (bleached area), in grandiorite.*

Coarse grained milky quartz is present in some of the narrow stockwork veins in the alkali-feldspar granite, and is commonly associated with minor carbonate and pyrite. Larger, coarse grained quartz veins are also present, and cross-cutting relationships suggest that they were formed at different stages during the early development of the hydrothermal system. These veins may document a history of dilatent movements (Plate 8). Large quartz veins on the Cat Arm road do not contain anomalous gold values.

There are numerous quartz veins throughout the French-Childs granodiorite. Many of these are deformed and probably predated the alteration system exposed on the Cat Arm road.

Mineralization

Native gold has not been observed. Total sulfide content of the altered rocks is generally less than 5 percent, except in areas of intense alteration (shear zones or tuffisite breccia) where concentrations up to 15 percent occur rarely. Fine grained pyrite is ubiquitous in mineralized shear zones and outcrops, and fine grained, acicular arsenopyrite is locally developed. Fine to coarse grained pyrite and arsenopyrite occur in fractures and as disseminations in the potassic-altered granite. No other sulfide minerals were identified in the field that could be related directly to the gold-bearing system. The French-Childs granodiorite does not contain visible sulfides.

Minor chalcopyrite occurs in folded quartz veins and in narrow, deformed, hematite-bearing pegmatite veins in the French-Childs granodiorite. Traces of chalcopyrite associated with minor pyrite were also observed in several subvertical

Plate 8: *Barren quartz vein in potassic feldspar granite. Note evidence for dilatent movement—steeper dipping vein is offset by shallow vien.*

quartz veins that cut the Beaver Brook quartzites. These veins trend 060, are up to 30 cm wide, and occur approximately 4 km south of Rattling Brook.

Structure

Numerous lineaments are present in the Grenville terrane where they are expressed as scarp faces and deep narrow canyons. The most prominent trends are 030, 060, 090, and 155 degrees. The lineaments trending 060 and 090 are parallel to, and continuous with, lineaments in the Paleozoic rocks. Lineaments trending 155 degrees appear to be confined to the Long Range inlier. Lineaments trending 030 are parallel to those in the Paleozoic terrane, and may represent either Paleozoic structures or reactivation of older Proterozoic structures. Bostock (1983) and Erdmer (1984, 1986) provide further discussion of late fractures and faults in the Long Range inlier.

Gold mineralization, minor sulfides, and carbonate and/or potassic alteration are associated with numerous lineaments and shear zones (of various trends) throughout the French-Childs granodiorite in the Jackson's Arm area. In addition, weak gold mineralization has been recorded from graphite- and chalcopyrite-bearing quartz veins associated with lineaments cutting gneiss and diorite to the west of the French-Childs granodiorite. Current data does not permit any conclusions about the large scale structural controls on the mineralizing system.

Model

A schematic diagram based on the rock section exposed along the Cat Arm Road is presented as Figure 3. This is an attempt to summarize the observations described above.

The core of the alteration system exposed on the Cat Arm access road, expressed by potassic-feldspar alteration, extends 400 m north and 100 m south of Rattling Brook. The contact with the external zone of steep, silica- and carbonate-bearing, altered shear zones and flat-lying, carbonate-altered fracture sets is transitional, and the shear zones and fracture sets occur up to 1 km to the south of the potassic-altered zone. The northern boundary of the alteration system is covered by overburden in a topographic depression. This depression may represent a fault or major fracture separating unaltered granodiorite to the north from the potassic-altered rocks.

Potassic-feldspar alteration is widely reported in the hot cores of many gold-bearing, epithermal systems (Buchanan, 1981), and is associated with lode-gold veins (Colvine *et al*, 1984). Pervasive, high temperature, potassic-feldspar replacement of pre-existing mineralogy is an inherent feature in the cores of large stockwork systems such as those of the Climax type (c.f. White *et al.*, 1981).

Age of Mineralizing System

Radiometric analyses are currently in progress in an attempt to date the mineralizing system and the magmatic and thermal events that have occurred in the Jackson's Arm area. Field observation suggests that the hydrothermal system postdates intrusion of the Long Range dikes (c.a. 614 Ma), and that the system is unconformably overlain by Eocambrian quartzite (c.a. 570-590 Ma). The trace of the unconformity on the east side of the granodiorite is not offset by fractures or possible shear zones related to the development of the hydrothermal system; this observation supports evidence for Precambrian fracturing and mineralization.

The indicated age range of mineralization is coincident with that of the Round Pond granite located to the west of Deer Lake, which has been dated at 602 ± 10 Ma (U-Pb, zircon; Williams *et al.*, 1985). This pluton is a variably foliated alkali-feldspar granite with slight alkaline affinities. Williams *et al.* (1985) have suggested that the Round Pond granite and associated volcanic rocks are related to rifting which preceded initiation of the Iapetus Ocean. This magmatic event may have provided a heat source for mineralization and alteration in the Grenvillian rocks. It is suggested here that the mineralization system in the Jackson's Arm area formed at this time.

However, further field evidence for age of mineralization is ambiguous. Firstly, the identification of the Long Range dikes in the French-Childs granodiorite needs to be confirmed, and secondly, the Eocambrian quartzite may have acted as an impermeable cap to trap hydrothermal fluids of a younger age. The presence of carbonate, sericite and pyrite in the quartzite overlying the alteration system may be interpreted to represent remobilization after deposition, or a later hydrothermal event. There is a strong possibility that the mineralizing event leading to gold precipitation resulted from intrusion of the Devils Room Granite in the Lower Devonian.

The gold-mineralizing event may also be related to the formation of epithermal-fumarolic gold-bearing systems located to the south of Sop's Arm (Tuach, *this volume*). These latter systems are almost certainly of Silurian age. Removal of the post-Devonian, dextral, strike-slip component of 15 km

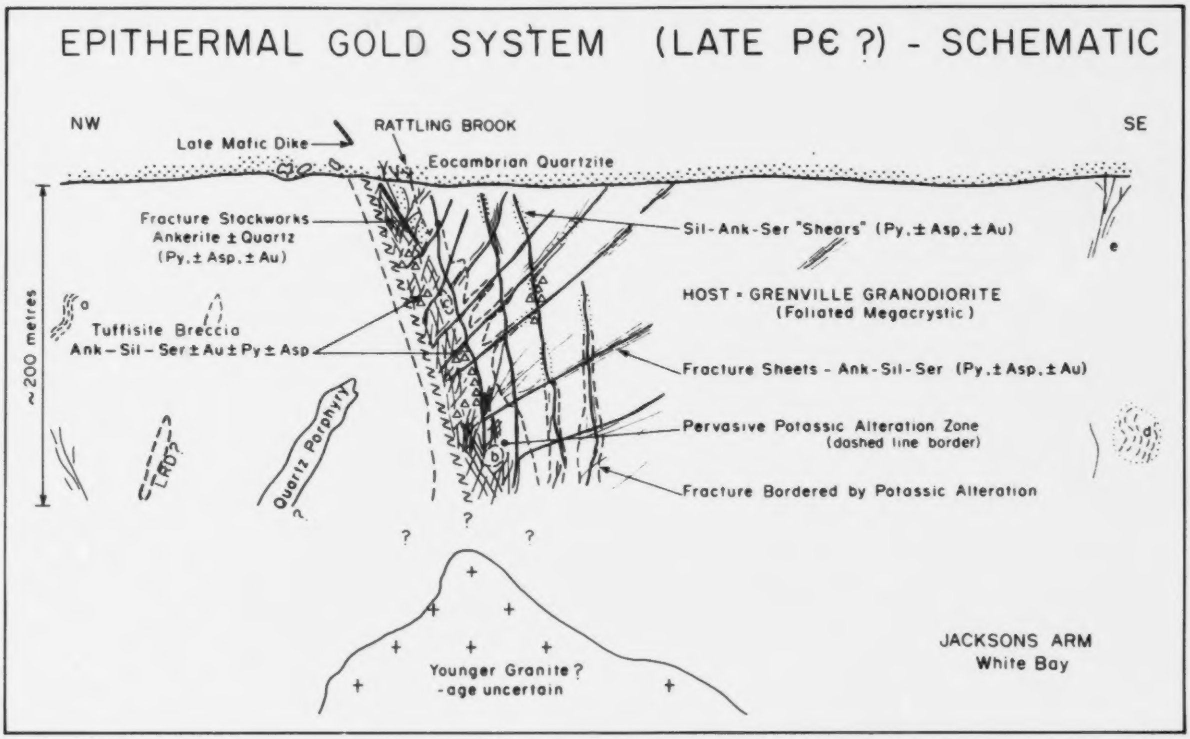
EPITHERMAL GOLD SYSTEM (LATE PЄ ?) - SCHEMATIC
NW
SE
RATTLING BROOK
Late Mafic Dike
Eocambrian Quartzite
Fracture Stockworks
Ankerite ± Quartz
(Py.± Asp.± Au)
Sil-Ank-Ser "Shears" (Py.± Asp.± Au)
HOST = GRENVILLE GRANODIORITE
(Foliated Megacrystic)
Tuffisite Breccia
Ank-Sil-Ser ± Au ± Py ± Asp
Fracture Sheets - Ank-Sil-Ser (Py.± Asp.± Au)
Pervasive Potassic Alteration Zone
(dashed line border)
Fracture Bordered by Potassic Alteration
~200 metres
LRD?
Quartz Porphyry
a
b
c
d
e
?
Younger Granite?
-age uncertain
JACKSONS ARM
White Bay

Figure 3: *Schematic representation of the alteration system exposed on the Cat Arm access road. (a), biotite schlieren; (b), amphibolite pod; (c), unaltered country rock; (d), gneissic xenolith; (e), isolated carbonate-bearing fracture sets. LRD - Long Range Dikes.*

on the Doucer's Valley Fault Complex, suggested by the correlation of the Devils Room Granite and the Gull Lake Intrusive Suite (Lock, 1969), juxtaposes the known gold mineralization in the Jackson's Arm area with that in the Sop's Arm area. Finally, there is the possibility of multi-stage mineralizing events.

DISCUSSION

This is the first significant gold prospect located in Grenvillian rocks of Newfoundland and Labrador, and therefore speculations on the metallogenic implications of the discovery may be useful.

If the metallogenic system is related to Late Precambrian tectonic structures and/or magmatism, then a broad-scale evaluation of the potential for gold mineralization throughout the Grenville Province is necessary. The lake sediment geochemical surveys of the Long Range area (Butler and Davenport, 1982) and of southern Labrador (Geological Survey of Canada, 1985) may assist in the selection of areas with above-average values for metals associated with vein-gold systems. Radiometric surveys may assist in the location of potassic-rich granites.

It is probable that the mineralization is related to the major lineament in the Sop's Arm - Jackson's Arm area, which is defined by the Doucer's Valley Fault Complex (Lock, 1969, 1972) and is accentuated by melange zones and multiple faults in the southern White Bay Allocthon (Williams, 1977). This lineament probably extends to the north along the eastern margin of the Long Range inlier, and southward becomes covered by Carboniferous (Visean) rocks in the Deer Lake Basin (Lock, 1972).

There is a variety of significant mineral deposits and minor prospects located adjacent to this lineament in the White Bay area (Figure 2). The Jackson's Arm gold prospects may be of Late Precambrian age. The Unknown Brook, Browning, Simms Ridge, Corner Brook, and Park prospects may represent epithermal-fumarolic environments of Silurian age (Tuach, *this volume*). The Turners Ridge and the Side Pond prospects are stockwork-galena deposits in brecciated Silurian limestones (Dimmel, 1979), and minor copper mineralization is reported to occur in brecciated Silurian rhyolite (Smyth and Schillereff, 1982). Fluorite mineralization is present in the Devonian Devils Room Granite, and fluorite, pyrite, and molybdenite occurences are associated with the Devonian Gull Lake Intrusive Suite.

North of the Sop's Arm area, in Canada Bay, high background to anomalous gold is present in sandstones of the Cambrian Maiden Point Formation and is associated with pyrophyllitic and sericitic alteration (P. Dean, personal communication, 1985). In the Deer Lake Basin to the south of the White Bay area, significant uranium-vanadium-silver-copper mineralization in sandstone may be associated with the Wigwam Fault (a possible extension or splay of the Doucer's Valley Fault Complex), and is thought to be of Permian age. A significant copper (bornite-chalcocite) prospect and minor uranium mineralization are located in Carboniferous limestone adjacent to the Wigwam Fault (Westfield Minerals Ltd. 1980-1983; Hyde, 1982) In addition, chalcocite-bornite-bearing rhyolite-breccia boulders have been noted in Carboniferous conglomerate, and chalcopyrite-bearing, chloritic volcanic rocks of possible Ordovician age in close proximity to the Wigwam Fault.

Thus a variety of mineralizing events of different ages are spatially associated with the major lineament in the area. The stratigraphic record indicates that this lineament was reactivated at various periods from the Late Precambrian to the Middle Carboniferous, and it is reasonable to suggest that the gold mineralization is related to this deep seated, long lasting structure. Gold mineralization may have occurred at different periods, or during a single mineralizing event.

Major lineaments are a favoured locale for gold mineralization (Colvine *et al.*, 1984; Landefeld, 1985). The Baie Verte Lineament (Hibbard, 1984), the Gander River Ultrabasic Belt (Blackwood 1982), and the Cape Ray Fault Zone (Wilton, 1984) in Newfoundland are recognized as having significant gold potential (see Figure 1).

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METALLOGENY OF THE TULKS HILL VOLCANICS, VICTORIA LAKE GROUP, CENTRAL NEWFOUNDLAND

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Mineral Deposits Section

ABSTRACT

The Tulks Hill volcanics are host to pyritic volcanogenic sulfides and are part of a thick sequence of volcanic and volcaniclastic rocks of the Victoria Lake Group. The group was deposited during the development of an early to middle Ordovician island arc. The volcanic rocks occur within two principal volcanic units, informally termed the Tulks Hill and Tally Pond volcanics. The volcanic rocks consist of intercalcated mafic and felsic rocks that are predominantly pyroclastic; mafic pillow lava is more common in the Tally Pond volcanics than in the Tulks Hill volcanics. The felsic volcanic rocks occur as laterally extensive sheets of crystal and crystal-lithic tuff, breccia and minor flows. Sedimentary rocks consist of sandstone, siltstone, shale, argillite, chert and minor interbedded conglomerate. The clastic sedimentary rocks appear to be derived from the adjacent and underlying volcanic rocks of the Victoria Lake Group.

There are six principal volcanogenic sulfide occurrences in the Victoria Lake Group, four in the Tulks Hill volcanics and two in the Tally Pond volcanics. The Tally Pond (Boundary) deposit and Burnt Pond prospect are both massive sulfides in the Tally Pond volcanics. The Tulks Hill, Tulks East and Victoria deposits are both stratiform, pyritic, Zn-Pb-Cu, massive sulfides in the Tulks Hill volcanics. The Jacks Pond deposit also occurs in the Tulks Hill volcanics, but aside from a zone of transported clastic sulfides, it mostly appears to be a stockwork zone. The mineralization is hosted by felsic crystal tuff, lapilli tuff and breccia, and are enveloped by an alteration halo characterized by silicification, sericitization and chloritization. Disseminated and stringer sulfides are also well developed in this halo.

INTRODUCTION

Metallogenic studies of the pre-Caradocian volcanic sequences of central Newfoundland were begun in July, 1984, concentrating on the Tally Pond volcanics (Kean, 1985). In 1985, studies were begun on the Tulks Hill volcanics. This involved regional rock geochemistry and detailed stratigraphic, structural and geochemical studies in the areas of known mineralization. A regional gold sampling program was also caried out over the Victoria Lake Group.

Access to the area is provided by woods roads from Millertown and Grand Falls. The area is characterized by a heavily forested (fir, spruce), gently undulating landscape with extensive glacial till cover. Consequently, except for the ridge that extends from Tulks Valley to Victoria River, bedrock exposure is poor.

Previous Work

Parts of the field area have been mapped in detail by mineral exploration companies, including ASARCO, Abitibi-Price and Noranda. The first systematic geological mapping was done at 1:250,000 scale by the Geological Survey of Canada (Riley, 1957; Williams, 1970). The Newfoundland Department of Mines and Energy has done 1:50,000 scale regional mapping of the King George IV Lake (12A/4), Victoria Lake (12A/6), Star Lake (12A/11E), Lake Ambrose (12A/16), Noel Paul's Brook (12A/9), Buchans (12A/15), Badger (12A/16) and Grand Falls (2D/13) map areas (Kean, 1977, 1979a,b, 1983; Kean and Jayasinghe, 1980, 1982; Kean and Mercer, 1981).

Brown (1952) proposed the name 'Victoria River Series' for the volcanic and sedimentary rocks in the Lake Ambrose - Victoria River area. Riley (1957) proposed the name 'Strides Group' for similar rocks in the western half of the Red Indian Lake map area. Kean (1977) abandoned these names and proposed and defined the 'Victoria Lake Group' to include all the pre-Caradocian volcanic and sedimentary rocks in this area (Figure 1).

Volcanogenic sulfide mineralization in the rocks presently assigned to the Victoria Lake Group was first discovered in the early 1900's near the mouth of the Victoria River and is known as Victoria Mine or the Victoria prospect. Subsequently, five other significant, volcanogenic, base-metal occurrences have been discovered: the Jacks Pond, Tulks East and Tulks Hill deposits in the Tulks Hill volcanics, and the Tally Pond (Boundary) deposit and the Burnt Pond prospect in the Tally Pond volcanics.

Regional Geology

The Victoria Lake Group underlies that part of the Dunnage Zone (Williams, 1979) of central Newfoundland which extends from Grand Falls in the northeast to King George IV Lake in the southwest, and from Red Indian Lake in the north to Noel Paul's Brook in the south.

The Ordovician geological development of the Dunnage Zone is recorded in three very broad geologic sequences:

(1) ophiolitic rocks which are interpreted to have formed as oceanic crust; where contacts are preserved,

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This project is a contribution to the Canada Newfoundland Mineral Development Agreement, 1984-1989

these are always the stratigraphically lowest units and they are believed to represent basement to most of the younger rocks in the Dunnage Zone;

(2) tholeiitic and calc-alkaline volcanic and subvolcanic rocks, and related volcaniclastic rocks; these rocks stratigraphically overlie the ophiolites and range up to 8 km in total thickness. The volcanic units consist of mafic and felsic, dominantly submarine, volcanic and volcaniclastic rocks, and are generally interpreted to represent the remains of early to middle Ordovician island arcs and back-arc basins;

(3) post island-arc shale and chert, and a flyschoid sequence of argillite, greywacke, and conglomerate; these rocks stratigraphically overlie many of the island-arc sequences and are in part derived from them. The sedimentary rocks range in age from Middle Ordovician to Early Silurian and are succeeded by younger Silurian rocks consisting of subaerial, mainly felsic, volcanic rocks and terrestrial sedimentary rocks.

In the south-central part of the Dunnage zone, the ophiolitic sequences are represented by the King George IV Lake, Annieopsquotch, Star Lake and Shanadithit Brook complexes. The King George IV Lake and Annieopsquotch complexes are faulted against the early to middle Ordovician island-arc sequences of the Victoria Lake Group to the southwest of Red Indian Lake, but are interpreted to have been originally in stratigraphic continuity (Herd and Dunning, 1979).

In the northeast, the Victoria Lake Group is conformably overlain by Caradocian black shales and cherts which in turn are conformably overlain by Middle Ordovician to Early Silurian flysch, argillite and conglomerate. Siltstone and tuffaceous sandstone of the Harbour Round Formation overlie the Victoria Lake Group in the Red Indian Lake area. This assemblage of rocks is in fault contact to the northwest with the Buchans Group and the Southwest Brook Complex along the Lloyds River - Red Indian Lake fault system.

The Rogerson Lake Conglomerate unconformably overlies the Victoria Lake Group along the group's southern and southeastern boundary. The contact, however, is generally fault modified. The Rogerson Lake Conglomerate is separated by a fault along its southeastern boundary from mafic volcanic rocks of the Pine Falls Formation and unnamed volcanic, sedimentary and metamorphic rocks south of Noel Paul's Brook.

Rocks of the Victoria Lake Group occupy a regional northeast-trending anticlinorium (Victoria Anticlinorium). Regionally, the sequence youngs northwesterly on the north limb and southeasterly on the south limb; however, there are many smaller scale, first order and second order folds resulting in variable facing directions. Unfortunately, poor exposure generally precludes deciphering the detailed structure.

GEOLOGY OF THE VICTORIA LAKE GROUP

The Victoria Lake Group can be divided into two major regional facies (Figure 1):

(1) volcanic rocks in the southwest (Tulks Hill volcanics) and along the southeastern margin (Tally Pond volcanics), comprising approximately 60 percent of the group, and

(2) a predominantly sedimentary facies to the northeast which is laterally equivalent to, and derived from, the volcanic rocks.

Limestone lenses near the top of the sedimentary facies and Tulks Hill volcanics have yielded late Llanvirn to early Llandeilo conodonts (Kean and Jayasinghe, 1982) and this is the only direct evidence as to the age of the Victoria Lake Group. Unpublished radiometric age dates on the Tally Pond volcanics indicates it is much older than this (Dunning, personal communication, 1985). This may necessitate the removal of the Tally Pond volcanics from the Victoria Lake Group. The sedimentary sequence is also conformably overlain by Caradocian graptolitic shale and chert (Kean and Jayasinghe, 1982). The thickness of the Victoria Lake Group cannot be estimated with any degree of certainty because of folding and poor exposure.

The Victoria Lake Group has an inhomogeneously developed, regional, penetrative foliation defined by chlorite, sericite, flattened clasts and crystal augen. This foliation is axial planar to tight to isoclinal folds. The rocks have been metamorphosed to the lower greenschist facies.

Volcanic Rocks

Volcanic rocks predominate in the southwestern part of the Victoria Lake Group, as well as along its southeastern margin. Two principal volcanic units, informally termed the Tulks Hill volcanics in the north and the Tally Pond volcanics in the southeast, occupy the north and south limbs of the Victoria Anticlinorium respectively. Both units are characterized by linear belts of predominantly felsic volcanics, in particular pyroclastics. Mafic flows are common in the Tally Pond volcanics but minor in the Tulks Hill volcanics. Small intercalations or lenses of volcanic rocks also occur within the clastic sedimentary rock facies of the Victoria Lake Group to the northeast.

Tulks Hill volcanics. The numerous bands and lenses of volcanic and volcaniclastic rocks that occur in a belt extending from Pat's Pond in the Victoria Lake map area to Victoria River on the southeastern shore of Red Indian Lake in the Lake Ambrose map area were defined by Kean and Jayasinghe (1980) as the Tulks Hill volcanics. The best exposures of these volcanic rocks occur at Tulks Hill in the Star Lake area. The Tulks Hill volcanics consist of predominantly felsic pyroclastic rocks and minor mafic volcanic rocks that are intercalated with well bedded, mafic to silicic, volcaniclastic rocks (including epiclastic / sedimentary rocks).

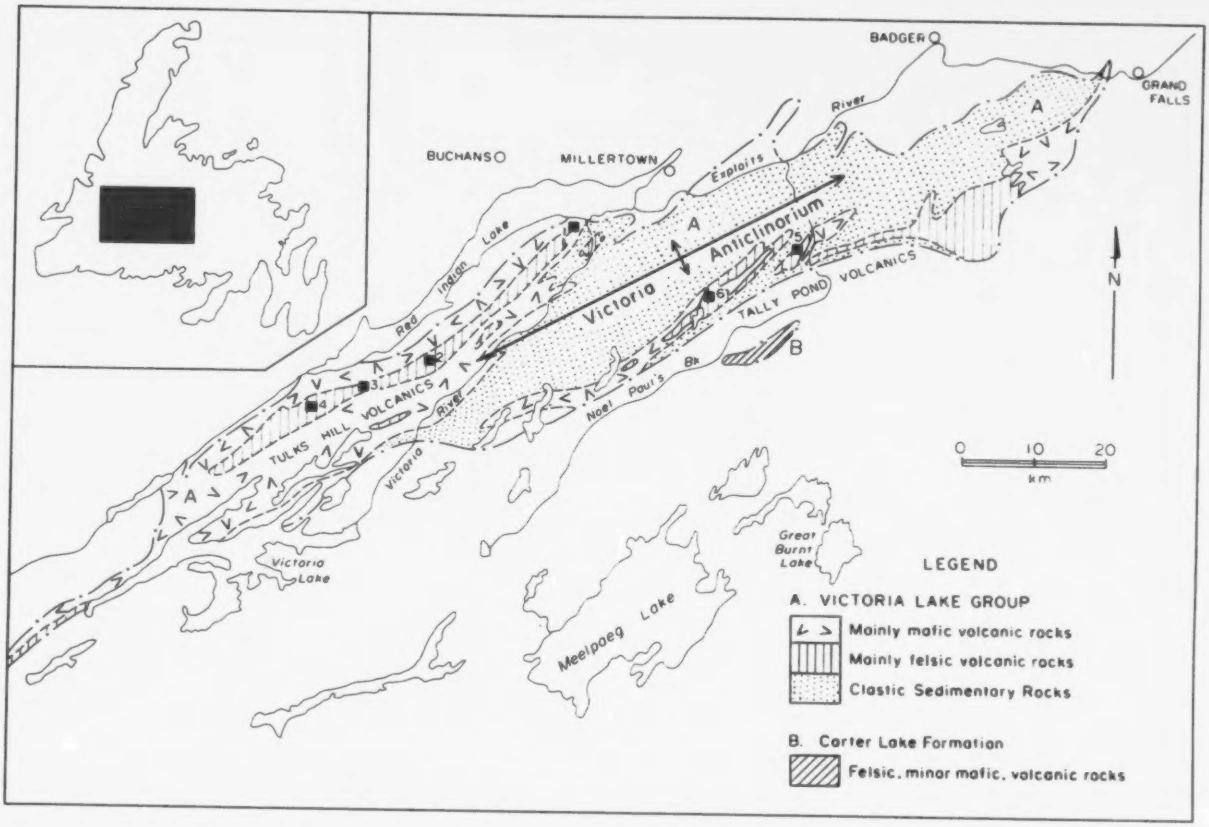
BADGER
GRAND FALLS
BUCHANS
MILLERTOWN
Exploits
River
Red
Indian
Lake
A
A
A
Victoria
Anticlinorium
TALLY POND VOLCANICS
TULKS HILL VOLCANICS
Victoria
River
Noel Paul's Bk
B
1
2
3
4
5
6
N
0
10
20
km
Victoria Lake
Great Burnt Lake
Meelpaeg Lake
LEGEND
A. VICTORIA LAKE GROUP
Mainly mafic volcanic rocks
Mainly felsic volcanic rocks
Clastic Sedimentary Rocks
B. Carter Lake Formation
Felsic, minor mafic, volcanic rocks

Figure 1: *Early to middle Ordovician volcanic-dominated island-arc sequences and massive sulfide deposits (solid squares) in central Newfoundland. Massive sulfide deposits: 1. Victoria Mine; 2. Jacks Pond; 3. Tulks East; 4. Tulks Hill; 5. Burnt Pond; 6. Tally Pond (after Swinden and Thorpe, 1984).*

The felsic volcanic rocks occur as laterally extensive sheets of crystal and crystal-lithic tuffs, breccias, porphyritic flows and shallow intrusives. The silica content of most of these rocks (unpublished chemical analyses) place them in the high dacite - low rhyolite range. Grayish, green and white quartz-crystal and crystal-lithic tuffs predominate. The quartz crystals range up to 1 cm across and are commonly blue. Locally, feldspar crystals are present. Flow-banded rhyolite occurs in places, especially west of Bobby's Pond. Locally, in the Jacks Pond area, the rocks have a granitic appearance and contain quartz, plagioclase, minor potassium feldspar, and a chloritized mafic mineral.

Pyroclastic breccias are also well developed in the felsic volcanic rocks. They contain angular to subrounded clasts, ranging from 0.5 to 45 cm in length, of green, felsic volcanic and rare mafic volcanic and sedimentary rock. Fine grained, greenish, felsic tuff constitute the matrix to the clasts. Locally the matrix is chloritic and has an intermediate composition.

The Victoria, Jacks Pond, Tulks East and Tulks Hill deposits are hosted by the felsic pyroclastic rocks of the Tulks Hill volcanics. Zones of silicified volcanic rocks occur in areas of hydrothermal activity associated with sulfide mineralization.

The mafic volcanic rocks are mainly pyroclastic, comprising mafic to intermediate aquagene tuff, lapilli tuff, agglomerate and breccia. Mafic lavas are mostly pillow lavas that generally exhibit small, commonly flattened, pillows with thin selvages and minor interpillow material. Pillow breccias occur locally. Massive unpillowed lavas are rare; some rocks mapped as such may actually be sills. The lavas are vesicular, contain calcite amygdules, and locally are variolitic; minor feldsparphyric phases are also present.

The host to these felsic and mafic volcanic rocks is a well-bedded sequence of volcaniclastic rocks. The unit consists of bedded, waterlain, reworked mafic to silicic tuffs, tuffceous sandstones, argillite and shale.

Tally Pond volcanics. The Tally Pond volcanics were defined by Kean and Jayasinghe (1980) as a belt of intercalated mafic and felsic volcanic rocks that extend from Quinn Lake in the southwest to Sandy Lake in the northeast. The mafic volcanic rocks comprise vesicular and amygdaloidal, generally pillowed, flows and mafic to andesitic tuff, agglomerate and breccia. Mafic pillow lava is more common in the Tally Pond volcanics than in the Tulks Hill volcanics. The pillows are generally small and have minor interpillow material; where present, the latter consists of mafic tuff (probably hyaloclastite) and minor green chert. The breccias contain mafic volcanic rock fragments that range up to 20 cm across. Some of the breccias contain pillow fragments and are interpreted as pillow breccias.

The felsic volcanic rocks, which are host to the Tally Pond deposit and Burnt Pond prospect, consist of tuff, lapilli tuff and breccia. Flow-banded rhyolite and rhyolitic breccia are locally present. Black, subvolcanic, quartz-feldspar porphyries are common. The lapilli tuff consists of subangular to rounded clasts of white, gray and green dacite and rhyolite, locally flow banded, in a fine grained to locally vitric, tuffaceous matrix. The breccias contain angular felsic volcanic fragments ranging from 3 to 45 cm in length in a tuffaceous matrix. Locally, gas breccias are developed which consist of flow-aligned, gas brecciated clasts in an aphanitic to vitric, siliceous matrix.

Sedimentary Rocks

Clastic sedimentary rocks constitute most of the northeastern facies of the Victoria Lake Group (Kean and Jayasinghe, 1982). This facies consists of sandstone (graywacke) with interbedded siltstone, shale, argillite, conglomerate and rare limestone. Siliceous siltstone and chert are more common near the top of the sequence. Locally, thin intercalations of mafic volcanic rocks are present.

The sedimentary sequence generally displays cyclic bedding. A typical cycle consists of a lower unit of conglomerate and pebbly sandstone constituting approximately 40 percent of the cycle. It generally has erosional bases with scour and fill structures, load casts and flame structures, and grades upwards into sandstone, which forms about 50 percent of the cycle. The sandstone grades from coarse at the bottom to fine towards the top, where faint laminations, cross-laminations or convolute laminations may be developed. The sandstone layer is overlain by thinly laminated siltstone, argillite or shale. The contact between the siltstone and underlying sandstone is sharp and free of erosional features. The cycles mainly include ABCE and ABE Bouma divisions and locally CE divisions (Bouma, 1962).

These clastic sedimentary rocks contain abundant volcanic detritus and both the amount and the coarseness of pyroclastic and epiclastic material increase towards the volcanic rocks of the Victoria Lake Group to the southwest. This suggests that the clastic sedimentary rocks were derived from the adjacent and underlying volcanic rocks of the Victoria Lake Group.

Intrusive Rocks

The Victoria Lake Group is intruded by linear bodies of medium grained quartz monzonite, minor granite and granodiorite, interpreted to be related to the volcanism (Kean and Jayasinghe, 1980, 1982). Fine to medium grained diorite and gabbro, including rare coarse grained phases, occur as small plugs and large bodies throughout the Victoria Lake Group.

Volcanogenic Sulfides

There are four principal volcanogenic base metal sulfide occurrences in the Tulk Hill volcanics, namely the Victoria, Jacks Pond, Tulks East and Tulks Hill deposits. The locations of these deposits and prospects are shown on Figure 1. The Tulks East and Tulks Hill deposits will be briefly discussed here. The Jacks Pond deposit is discussed by Evans and Kean (this volume); the Victoria prospect was not included in this study.

Tulks Hill deposit. The Tulks Hill deposit, a significant Zn-Pb-Cu, volcanogenic, massive sulfide deposit, located near the southwestern extremity of the felsic pyroclastic rocks of the Tulks Hill volcanics, was discovered by ASARCO personnel the early 1960's. The deposit consists of four stratiform sulfide lenses with a total tonnage of approximately 750,000 tonnes grading approximately 5 to 6 percent Zn, 2 percent Pb and 1.3 percent Cu, 41 g/t Ag and 0.4 g/t Au (Kean and Thurlow, 1976; Jambor, 1984).

The host rocks to the deposit are well exposed in Tulks Hill and the deposit is surficially marked by gossans. The mineralization occurs within northeast trending, steeply northwest dipping, felsic volcanic rocks of greenschist metamorphic grade. The host volanic rocks are sericite schist derived from felsic lapilli tuff, quartz (± feldspar) crystal and crystal-lithic tuff. Minor tuffs of intermediate composition and diabase/andesite dikes or sills are intercalated with the felsic rocks. The dikes and sills locally contain quartz and/or carbonate amygdules. Sub-volcanic intrusions of quartz and minor feldspar porphyry and aphanitic rhyolite are also present.

An inhomogeneously developed regional schistosity, coplanar to bedding, is best developed in the pyroclastic rocks. This penetrative fabric is axial planar to tight to isoclinal folds and is defined by sericite, chlorite and locally quartz segregations. Volcanic-breccia fragments have undergone moderate flattening within the foliation planes. A fracture cleavage and kink bands constitute less well-developed, later deformation. Faulting generally parallels the regional foliation trend; however, minor cross-faulting also has taken place. The northeast trending Tulks Valley fault parallels the regional trend of the volcanic rocks and is the major fault in the area, forming the northern boundary of Tulks Hill.

The four sulfide lenses or zones are termed the T_1, T_2, T_3 and T_4 lenses. Since folding in this area is isoclinal, some of the lenses may be structural repetitions of the same horizon. Morton (1984) interpreted the T_3 and T_4 lenses to be folded equivalents of the same stratigraphic horizon based on mineral zoning and distribution of alteration. However, evidence from this study suggests that reverse mineralogical zoning also occurs at depth in the T_3 lens. Both the hangingwall and the footwall display hydrothermal alteration associated with the mineralizing process, and it is not everywhere demonstrable which is the stratigraphic footwall on the basis of intensity of alteration.

The lenses are roughly tabular to lensoid in shape and dip 70° to the northwest. They are predominantly pyritic (approximately 70 percent) with sphalerite being the main economic mineral. Lesser galena and chalcopyrite are present in approximately equal amounts. Arsenopyrite, tetrahedrite - tennantite and pyrrhotite are variably distributed accessory sulfide minerals. Minor magnetite occurs in the

Table 1. Grade and tonnage data for the Tulks East deposit (from Barbour and Thurlow, 1982)

ZONE	TONNAGE	GRADE				
		Au g/t	Ag g/t	Cu %	Pb %	Zn %
A-Zone	4,500,000+	Tr.	8.5	0.24	0.12	1.50
B-Zone	200,000	0.14	58.7	0.66	1.26	8.69
C-Zone	900,000	Less than 1 percent combined base metals				

T_1 and T_2 lenses. Oxidation and supergenic alteration minerals include digenite, covellite and anglesite (Jambor, 1984). Most of the silver is attributable to argentian tetrahedrite and tennantite and nearly all of the gold occurs as native gold (Jambor, 1984). Dolomite, calcite and barite are either associated with quartz or disseminated among the sulfides.

The pyrite is euhedral to anhedral and generally fine grained, although locally it is coarse grained. No colloform or fromboidal textures were observed. The sphalerite is generally brown and fine to medium grained and is mostly associated with abundant pyrite. Galena is fine to medium grained and occurs as patches in, or at the rims, of sphalerite grains. Sulfide layering is generally well developed, particularly in the sphalerite/pyrite rich parts; chalcopyrite-sphalerite banding is also locally developed. Chalcopyrite, galena and sphalerite are also present in quartz veins.

The contacts of the massive sulfides with the hangingwall and footwall vary from sharp to gradational. Both the structural hangingwall and footwall are hydrothermal altered; however in some areas it appears to be more intensely developed in the structural footwall. Siliceous alteration characterized by gray silica veinlets, and greenish to yellowish sericite-rich seams in gray to white, and bleached, lapilli tuff and quartz-crystal tuff is the predominant alteration type. Disseminations and stringers of sulfides, predominantly pyrite-rich but also chalcopyrite-rich, with lesser galena and sphalerite, are variably developed. Minor chlorite-dominated alteration assemblages are locally developed within the overall area of siliceous alteration. Morton (1984) reported that chlorites from the mineralized sequences show a Mg-enrichment trend from the least to most mineralized rock.

Tulks East deposit. The Tulks East deposit, a low grade Zn-Pb-Cu, volcanogenic, massive sulfide deposit, is located in the Tulks Hill volcanics approximately eight kilometres northeast of the Tulks Hill deposit. It was discovered in 1977 by personnel from the Mineral Resources Division of Abitibi-Price. It consists of three stratiform massive sulfide lenses termed the A, B and C zones which contain approximately 5,600,000 metric tonnes of pyritic massive sulfides with low base metal values (see Table 1). The host rocks to the deposit are poorly exposed and the mineralization is best studied in drill core.

The mineralization occurs in steeply northeast trending, northwest dipping, felsic, fine grained tuffs and breccias which have been metamorphosed to lower greenschist facies. The host rocks contain an inhomogeneously developed, regional penetrative foliation which is axial planar to tight to isoclinal folds. The foliation is defined by sericite, chlorite and flattened clasts and the rocks are in places sericite schists. However, overall the rocks of this area are not as deformed as the rocks hosting the Tulks Hill deposit. The host sequence is bounded along its northwestern side by the Tulks Valley fault, which juxtaposes it against an interbedded sequence of felsic pyroclastics, mafic tuffs and fine grained clastic sedimentary rocks (black shale, siltstone and mudstone).

Host rock types to the mineralization are predominantly quartz-crystal and crystal-lithic tuffs, lapilli tuff and locally breccia. Green, aphanitic, dacite dikes containing quartz phenocrysts occur locally. An alteration zone of pyritization, sericitization, bleaching and silicification is developed in the host rocks. Minor quartz, quartz-carbonate, and dolomite veins are locally present. Barbour and Thurlow (1982) estimated the surface dimensions of this alteration halo to measure approximately 1600 m along strike and 200 m across strike. Minor mafic tuffs and widespread andesitic to diabasic dikes and sills occur within the felsic rocks. Locally they contain quartz and/or calcite amygdules.

The lenses are tabular to lensoid in shape, dip 70° to the northwest and plunge 45 to the north (Barbour and Thurlow, 1982). The B-zone is situated 15 m stratigraphically above the A-zone, and the C-zone is situated 250 m east of the A and B-zones within the same stratigraphic unit. The lenses consist predominantly of fine to coarse grained, saccharoidal pyrite with varying amounts of sphalerite, galena, chalcopyrite and gangue of quartz, chlorite, calcite and dolomite. The sulfides consist of massive non-banded and banded varieties. The banding is primarily defined by alternating sphalerite and pyrite layers. Chalcopyrite locally forms layers, but generally occurs as blebs within the pyrite. Galena occurs both as blebs within sulfides and as galena and galena/quartz veins. Locally developed mineralogical zoning within the sulfides display both normal and reverse sequences in what appears to be a non-systematic pattern; however, at this stage it is difficult to interpret the meaning of this. Brecciation textures are locally well developed in the sulfides and are interpreted to be tectonic. The contacts with the host rocks are generally sharp with narrow margins of profuse sulfide dissemination. The lower contact, however, is locally gradational over a few meters.

Both A and B zones appear to be richer in base metals in their northeastern ends. The B-zone contains the lowest tonnage and highest grade (see Table 1).

The hangingwall and footwall rocks display evidence of hydrothermal alteration associated with the mineralization process. Sericitic to chloritic, gray to green pyroclastics, and intermediate dikes and sills, constitute the hangingwall. Mineralization includes disseminated and stringer pyrite with lesser sphalerite and chalcopyrite; minor quartz and dolomite veins are also present. The footwall is generally more silicified and sericitized and commonly has a bleached appearance. Chloritization is sporadically developed, except for the C-zone where it is the predominant alteration. The silicification occurs both as a pervasive replacement by silica and as narrow, gray silica veinlets. Pyrite and minor sphalerite and chalcopyrite occur as disseminations and stringers. Dolomite is dispersed throughout the rocks and also forms veins.

SUMMARY AND CONCLUSIONS

The Tulks Hill volcanics represent a major volcanic complex in the southwestern part of the Victoria Lake Group. Felsic volcanic rocks of the Tulks Hill volcanics represent a significant time-stratigraphic horizon of extensive felsic volcanic activity within a dominantly mafic to intermediate volcaniclastic sequence. The felsic rocks appear to have been deposited near a number of volcanic edifices located along a fissure or fault-controlled lineament. This volcanic activity was accompanied by hydrothermal activity which resulted in deposition of metallic elements, mainly Zn, Pb and Cu, near the stratigraphic top of the felsic volcanic rocks.

Exhalative sulfides are well developed as the Tulks Hill and Tulks East deposits and stockwork alteration and mineralization underlie these as well as being the predominate type of mineralization at Jacks Pond. There is excellent potential for more massive sulfides, as well as gold minerlization, in the belt.

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GEOLOGY OF THE JACKS POND VOLCANOGENIC SULFIDE PROSPECTS, VICTORIA LAKE GROUP, CENTRAL NEWFOUNDLAND

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ABSTRACT

The Jacks Pond prospects occur in the felsic volcanic rocks of the Tulks Hill volcanics, Victoria Lake Group. The Tulks Hill volcanics consist predominantly of linear belts of felsic pyroclastics and minor mafic volcanic rocks that are intercalated with mafic to felsic, fine grained, volcaniclastic rocks. The host rocks to the mineralization are variably altered, fine grained, felsic, lapilli tuff, vitric tuff and crystal-vitric tuff.

The Jacks Pond prospects consist of four pyritic, volcanogenic sulfides with low base-metal values. The mineralization occurs mainly as disseminated and stringer sulfides in an alteration stockwork containing minor, exhalative sulfides that exhibit detrital textures. Chloritization, sericitization and silicification are characteristic alteration types.

INTRODUCTION

The Jacks Pond area lies in the Lake Ambrose (12A/10) map area and is accessible by logging roads from Millertown. It is located approximately 10 km northeast of the Tulks East deposit (Figure 1).

During the 1985 field season, 1:13,320 scale mapping was conducted in the vicinity of the Jacks Pond volcanogenic sulfide prospects. A detailed study of drill core from the sulfide lenses was carried out in conjunction with the surface mapping. The present investigation forms part of a B.Sc. honours thesis by Evans, which will examine the general geology, alteration and mineralogy of the deposit.

The Jacks Pond sulfide occurrences were discovered in 1980-81 by personnel from the Mineral Resources Division of Abitibi-Price Inc. The mineralization consists of four dominantly pyritic lenses containing minor amounts of base metals, and range in size form 200,000 to 900,000 tonnes (Barbour and Thurlow, 1982). The sulfide bodies are not exposed and can only be studied in drill core. Two new pyritic, base-metal showings were also discovered during the course of this study.

GENERAL GEOLOGY

The Jacks Pond massive sulfides occur in felsic pyroclastic rocks of the Tulks Hill volcanics near the stratigraphic top of the Victoria Lake Group (Kean and Jayasinghe, 1980). The Victoria Lake Group is a northeast-trending belt of felsic and mafic volcanic rocks, and volcaniclastic and epiclastic volcanic rocks which extends from the Burgeo highway northward to Grand Falls. Limestone lenses near the top of the sedimentary/epiclastic rocks in the northeast have yielded late Llanvirn to early Llandeillo conodonts (Kean and Jayasinghe, 1982). The Victoria Lake Group is thus interpreted to be part of the pre-Carodocian island-arc volcanism in central Newfoundland (Kean and Jayasinghe, 1980). For a more detailed discussion of the regional geology, readers are referred to Kean and Evans (*this volume*). The Tulks Hill volcanics form a 65 km long belt, extending from Pats Pond in the southwest to the mouth of Victoria River in the northeast. Structurally, the rocks occupy the north limb of the Victoria Anticlinorium. The volcanic rocks consist of felsic tuff, lapilli tuff, quartz crystal tuff, breccia and porphyry, intercalated with intermediate and mafic pyroclastic and volcaniclastic rocks (Kean and Jayasinghe, 1980). Mafic flows are not widely developed but are present throughout the unit.

Tulks Hill Volcanics (Units 1 to 5)

The Tulks Hill volcanics consist predominantly of felsic, quartz crystal tuff and crystal-lithic tuff in the Jacks Pond area. Mafic volcanic rocks underlie a small portion of the southern part of the study area. Silicification of the felsic rocks varies from weak to intense; the rocks in the vicinity of the sulfide lenses are highly silicified and sericitized. Pervasive silica replacement obliterates the original textures in the highly silicified areas.

The rocks contain an inhomogeneously developed, penetrative foliation, defined by sericite, chlorite and flattened clasts and crystals; it is axial planar to tight to isoclinal folds. A cleavage-bedding intersection in subunit 3b suggests

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This project is a contribution to the Canada-Newfoundland Mineral Development Agreement, 1984-1989

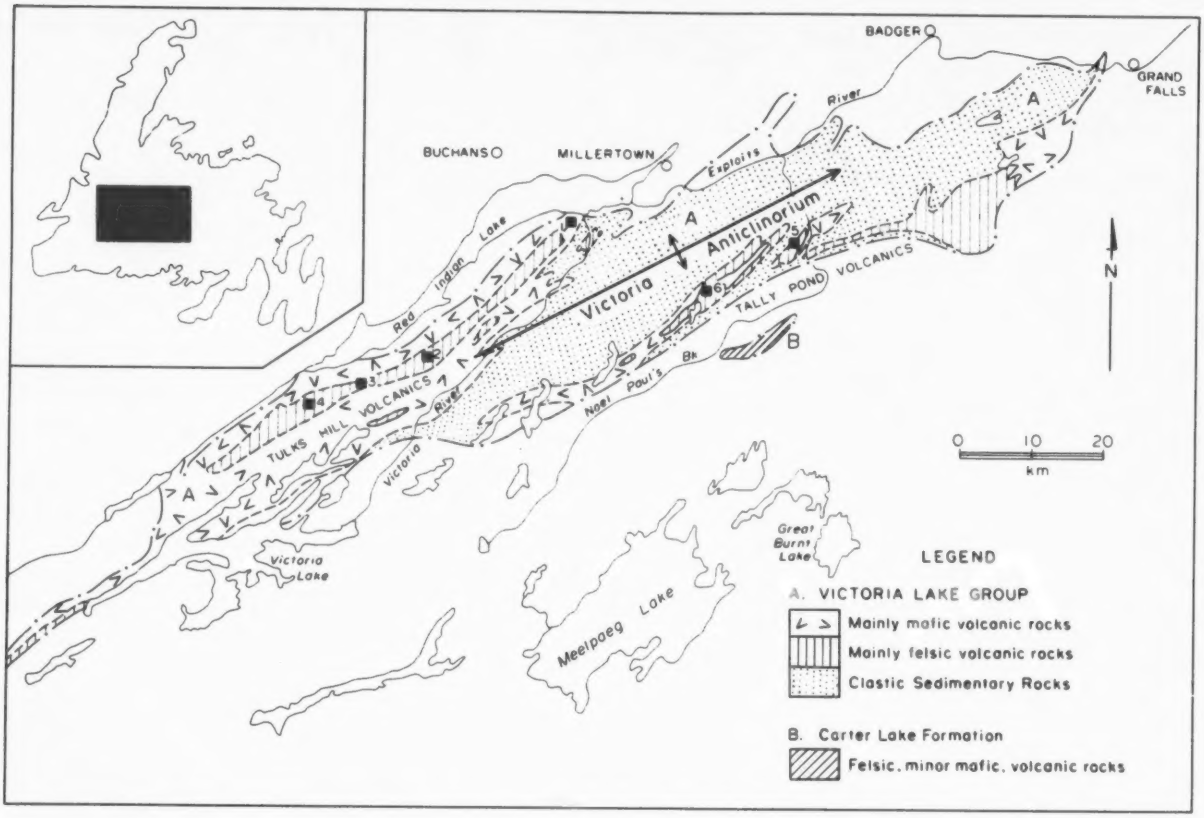
BADGER
GRAND FALLS
BUCHANS
MILLERTOWN
Exploits River
Red Indian Lake
Victoria Anticlinorium
A
B
TULKS HILL VOLCANICS
TALLY POND VOLCANICS
Victoria River
Noel Paul's Bk
Victoria Lake
Great Burnt Lake
Meelpaeg Lake
1
2
3
4
5
6
N
0
10
20
km
LEGEND
A. VICTORIA LAKE GROUP
Mainly mafic volcanic rocks
Mainly felsic volcanic rocks
Clastic Sedimentary Rocks
B. Carter Lake Formation
Felsic, minor mafic, volcanic rocks

Figure 1: *Early to middle Ordovician volcanic-dominated island-arc sequences and massive sulfide deposits (solid squares) in central Newfoundland. Massive sulfide deposits: 1. Victoria Mine; 2. Jacks Pond; 3. Tulks East; 4. Tulks Hill; 5. Burnt Pond; 6. Tally Pond (after Swinden and Thorpe, 1984).*

that these rocks occupy the south limb of a synform that closes to the northeast. The northeastward extension of the Tulks Valley fault transects the Tulks Hill volcanics in the northern part of the area.

The Tulks Hill volcanics in this area can be locally subdivided into five units on the basis of rock type, composition and degree of alteration (Figure 2); these subdivisions do not necessarily represent stratigraphic units.

Unit 1 consists of dark greenish-gray, chloritic, mafic, tuffaceous rocks and massive mafic rocks. Aphanitic mafic rocks of massive appearance, locally containing calcite amygdules, may be flows; these are referred to as subunit 1a. Subunit 1b consists of dark greenish-gray, fine grained, locally plagiophyric, mafic tuff. The outcrops have a scalloped appearance, which is interpreted to be the result of differential weathering of carbonate-rich zones.

Unit 2 consists of white and rusty weathering, sericitic, crystal and crystal-lithic, felsic tuff, intercalated with zones of chlorite-rich tuff. The felsic tuff is light grayish-green on fresh surfaces and contains abundant quartz crystals up to 1 cm across. Feldspar crystals are locally present and are generally small. Lithic clasts appear to be restricted to narrow zones or beds and are generally of lapilli size. Locally, however, felsic clasts up to 15 cm by 45 cm were observed. The matrix to the clasts is a quartz crystal tuff.

The chloritic zones generally form narrow bands that are locally up to 2m wide. Feldspar crystals (up to 1 cm in length) and small quartz crystals are also present in the chloritic zones. Disseminated pyrite and stringers of coarse grained pyrite also occur.

Unit 3 consists predominantly of quartz crystal tuffs containing local concentrations of feldspar. It also includes breccias, dolomitic beds and silicified tuffs, which are host to volcanogenic sulfides. The unit is subdivided into five subunits based on rock types.

Quartz crystal tuffs, which are locally feldspar rich, constitute subunit 3a. This subunit is slightly silicified and sericitized. It weathers white to gray and is generally light greenish-gray on fresh surfaces. Milkly-white or blue quartz crystals range in size from 2 mm to 1 cm across. Limonitic coatings and flecks are common on fracture and cleavage surfaces within the tuffs, and there is abundant disseminated pyrite. A narrow zone or band of fine to coarse grained, massive pyrite containing quartz gangue occurs in this unit along the south shore of Cathy's Pond.

Subunit 3b is a variably silicified, fine grained, felsic tuff that hosts the Jacks Pond mineralization. The subunit is generally white weathering and greenish-gray on fresh surfaces. Areas of intense silicification are marked by pale-green, fine grained rocks, which give a massive appearance to some outcrops. However, zones containing preserved fragmental textures were observed in one locality. Narrow, intensely sericitized zones are common. Disseminated pyrite and limonitic flecks, and quartz-carbonate veins and veinlets are common.

A narrow zone of fine grained, green to black chlorite containing abundant granular and euhedral pyrite occurs within the silicified felsic volcanic rocks. Rusty quartz-carbonate veins, up to 7.5 cm wide, cut the chloritic zone, and also contain granular pyrite and minor galena.

A breccia, consisting of angular fragments of felsic and minor mafic volcanic rocks in a quartz crystal tuff matrix, constitutes subunit 3c. It weathers rusty white due to the abundance of disseminated pyrite. The fragments are slightly flattened and range in size from less than 1 cm^2 to 25 cm by 50 cm. The felsic fragments are generally quartz porphyritic. The matrix is slightly silicified and sericitized and cut by numerous quartz veins.

Subunit 3d consists of tuffaceous rocks characterized by large, slightly flattened, milky-white, quartz crystals and crystal fragments up to 1.5 cm by 2 cm in size. The greenigh-gray matrix of the tuffs is fine grained, slightly sericitic and siliceous.

Subunit 3e forms a narrow band or bed of dolomite and dolomite-rich tuffs. The dolomitic rocks are beige on weathered surface, brownish-gray on the fresh surface, and are partially recrystallized. Euhedral pyrite, locally up to 3 mm across, is generally present. Dolomitic rocks are not extensive in the Victoria Lake Group, but have been reported from other mineralized areas. For example, in the Victoria Mine area to the northeast, massive to bedded dolomite is associated with lead-zinc mineralization (Kean and Jayasinghe, 1980).

Unit 4 consists of quartz crystal tuffs. It is lithologically similar to subunit 3a, but is more silicified; the boundary between the two is interpreted to be gradational. The unit is generally white to gray weathering, and exhibits quartz veining and pervasive silica replacement, particularly in the northern portion of the unit. The southern part of Unit 4 contains numerous narrow zones of sericitic and highly bleached tuffs, each separated by massive, intensely silicified tuffs. The sericitic areas are locally extremely hematitic and rusty. Pyrite, chalcopyrite, galena and sphalerite occur as small patches and disseminations in the altered zones.

Unit 5 consists predominantly of coarse grained, pyroclastic breccia; fine grained, locally carbonate-rich, tuffs occur in the western part. Unit 5 is juxtaposed against Unit 3 by the northeast extension of the Tulks Valley fault from the Tulks East deposit area. In the Jacks Pond area, the fault is expressed by a linear EM anomaly which passes through Cathy's Pond (J. G. Thurlow, personal communication, 1985).

Subunit 5a consists of breccias that contain abundant, angular, felsic blocks ranging in length from 1 cm to 25 cm. Vesicular and chloritic mafic blocks are locally present; these appear to increase in abundance to the west. The matrix of the breccia is white weathering and consists mainly of feldspar crystals and fragments up to 1 cm in size.

Subunit 5b is a sheared, fine grained, carbonate-rich, felsic, lapilli tuff that is generally purplish-gray. Sandy, clastic textures occur locally and may indicate reworking. Brown weathering, white to gray, fine grained dolomite forms a wide band within the felsic tuffs. Euhedral pyrite cubes (2 to 3 mm across) are common.

Volcanogenic Sulfides

The Jacks Pond deposits consist of base metal volcanogenic sulfides concentrated mainly in four lenses, herein called A, B, C and D, and are located to the south of Cathy's Pond (Figure 2). They range in size from 200,000 to 900,000 tonnes (Barbour and Thurlow, 1982). Two significant new showings were discovered during the course of this study (Figure 2). The mineralization in the Jacks Pond area is predominantly pyritic with low base-metal values. Precious metal content ranges from very low to trace amounts.

Jacks Pond Prospects. There appears to be at least two different styles or types of mineralization in the Jacks Pond area. The first type, represented by lenses A and B, is characterized by ellipsoidal mineralized zones consistng of a massive pyritic core that is gradational into stringer and disseminated pyrite. This mineralization is hosted by fine grained, gray to green, feldsparphyric, crystal-vitric tuff and lapilli tuff. The lapilli clasts have indistinct boundaries and appear to be partially replaced. These mineralized zones appear to be stratiform, forming tabular-shaped, northeast-trending and southeast-dipping bodies. The pyritic core consists of massive veins or lenses that have a maximum thickness of 1.5 m and are separated from each other by narrow, sericitic, chloritic, and silicified zones. These zones may be either unmineralized or contain up to 20 to 30 percent pyrite. The pyrite is medium to coarse grained, granular, euhedral to subhedral; locally it is rounded. The semi-massive pyritic core grades into zones containing 10 to 60 percent disseminated and stringer pyrite in a matrix of black chlorite and quartz. Quartz, chlorite and minor calcite gangue in places constitute up to 80 to 90 percent of the zone. Chalcopyrite is a minor constitutent in these lenses and occurs as blebs and stringers within the pyrite. Copper assays up to 2 percent, traces of galena and sphalerite, and silver values have been reported (Barbour and Thurlow, 1982).

A gradational, hydrothermal alteration envelope surrounds the mineralization. The rocks structurally underlying the mineralization to the north display varying degrees of chloritization, sericitization, pyritization and silicification. Minor quartz and calcite veinlets occur locally. To the south, the rocks structurally overlying the mineralization are also variably chloritized, sericitized, pyritized and silicified. Chlorite alteration appears to be slightly more strongly developed than the other alteration types. Coarse grained,

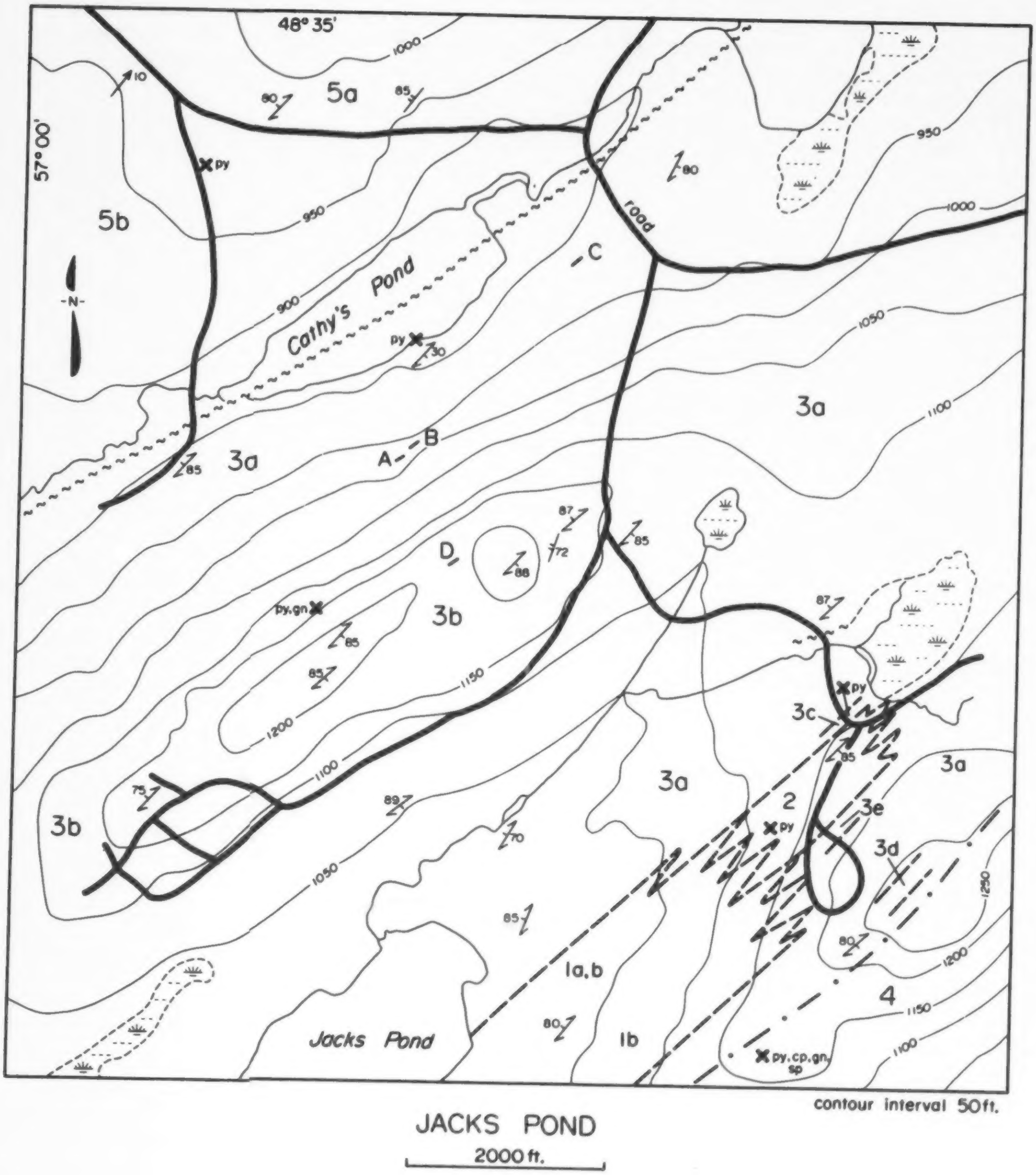
48° 35'
57° 00'
-N-
5a
5b
3a
3b
3c
3d
3e
2
4
la,b
lb
Cathy's Pond
Jacks Pond
road
A
B
C
D
py
py,gn
py,cp,gn,sp
10
80
85
30
87
72
88
85
75
89
70
80
1000
950
900
1050
1100
1150
1200
1250
contour interval 50ft.
JACKS POND
2000 ft.

Figure 2: *Geology of the Jacks Pond area.*

LEGEND

MIDDLE ORDOVICIAN OR EARLIER

5	5a, felsic, pyroclastic breccia with matrix of feldspar crystal tuff; 5b, carbonate-rich, felsic, lithic, lapilli tuff.
4	Silicified, quartz crystal tuff.
3	3a, felsic, quartz (± feldspar) crystal tuff; 3b, silicified felsic tuff; 3c, felsic breccia and crystal tuff; 3d, coarse grained, quartz crystal tuff; 3e, dolomite and dolomitic tuff.
2	Felsic quartz crystal tuff and crystal-lithic tuff.
1	1a, chloritic mafic flow (?), locally containing calcite amygdules; 1b, mafic tuff.

granular and euhedral pyrite occurs as disseminations and stringers throughout the rocks and locally reaches up to 80 percent; chalcopyrite values up to 5 percent have been reported (Barbour and Thurlow, 1982). The pyritic stringers may also contain quartz and chlorite and vary in thickness from 1 cm to 1 m. Quartz veining is also developed.

The alteration varies in intensity and does not appear to be stratigraphically controlled; however, in places the silicification appears to be more strongly developed in the structural footwall. The stratigraphic footwall cannot be definitely determined on the basis of alteration. The limited available evidence suggests that these lenses could be part of a hydrothermal alteration system or stockwork, rather than exhalative or massive sulfides.

The second type of mineralization, represented by lenses C and D, has a syngenetic aspect to it. The C lens consists of massive, fine grained, saccharoidal pyrite, with quartz generally present as gangue. Chalcopyrite occurs as a minor constituent in the pyrite, and traces of sphalerite and galena are present. There is no well defined banding or layering and the lens has a massive appearance suggestive of a syngenetic origin. Contacts with the host rocks are sharp.

The structural hangingwall to the C lens consists of gray to green tuff and lapilli tuff that are sericitized, veined by quartz and moderately pyritized. Small feldspar crystals occur locally. The structural footwall consists of moderately sericitized tuff and lapilli tuff. Quartz veining and pyrite stringers are generally present. A unit of aphanitic, amorphous, green to gray vitric rock is present in the deeper levels of the footwall. This rock is locally feldsparphyric and is transected by seams of green and yellow sericite. It may be part of a rhyolitic dome structure.

The D lens consists of zones of fine grained, locally layered, massive pyrite, with some zones displaying clastic textures. Clasts consist of pyrite and minor chalcopyrite, and felsic volcanic rocks. The sulfides are in gradational contact with overlying tuffaceous rocks, marked by a decrease in the amount of sulfide clasts and sulfide in the matrix. The D lens is in sharp contact with structurally underlying rocks. The lens contains minor chalcopyrite and traces of sphalerite and galena.

The structural hangingwall to the D lens consists of white, bleached, silicified rhyolite and felsic tuff, cut by quartz veinlets and pyrite stringers and disseminations. The structural footwall consists of gray, sericitic tuff with pyrite and sericite veinlets.

C and D lenses are interpreted to be syngenetic massive sulfides deposited on the surface at the rock/water interface. The D lens consists of detrital sulfide fragments, thus supporting the conclusion of Barbour and Thurlow (1982) that, at least in part, it was mechanically transported.

Cathy's Pond showing. This prospect, discovered during the current study, forms a small, partially submerged, exposure on the south shoreline of Cathy's Pond. It consists of fine to medium grained, semi-massive to massive, banded pyrite with a quartz gangue. It occurs in highly silicified and bleached quartz-feldspar crystal tuff.

Side of the Hill showing. This prospect, also discovered during the current study, occurs on the southwest side of the hill to the east of Jacks Pond. It consists of disseminations and patches of pyrite, chalcopyrite, galena and sphalerite in bleached, sericitic quartz-crystal tuffs. The sericitic zones are generally white weathering but in places are hematitic and rusty weathering. The mineralized, sericitized volcanic rocks form narrow zones up to 1.5 m wide in highly silicified, massive looking, quartz crystal tuffs.

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EPITHERMAL GOLD MINERALIZATION IN LATE PRECAMBRIAN VOLCANIC ROCKS ON THE BURIN PENINSULA

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INTRODUCTION

The project was initiated in 1984 to document gold-bearing rocks in the area of the Swift Current Granite and was continued and expanded during the 1985 field season. Its objectives were: 1) to see if the alteration belts defined by Huard and O'Driscoll (1985) extended to the south, 2) to do reconnaissance exploration for similar or related rocks around the Cape Roger Mountain Batholith and the 'Knee granitoids' (informal name), and 3) to determine the extent and gold content of the specularite-rich breccias at the Hickey's Pond showing, which were shown in 1984 to contain the highest gold concentrations.

The map areas (Figure 1) were previously included in 1:250,000 scale mapping by Anderson (1965), and 1:50,000 scale mapping by Bradley (1962), O'Driscoll and Hussey (1978), O'Driscoll (1978), O'Brien and Taylor (1979, 1983), O'Brien and Nunn (1980) and O'Brien *et al*. (1984). The mineral potential of the area was discussed by Taylor *et al*. (1979). Reconnaissance exploration for fluorite and base metals was carried out by Allied Chemical Corporation (Fitzpatrick and Howse, 1973) and Serem Ltée (Schrijver, 1972, 1973).

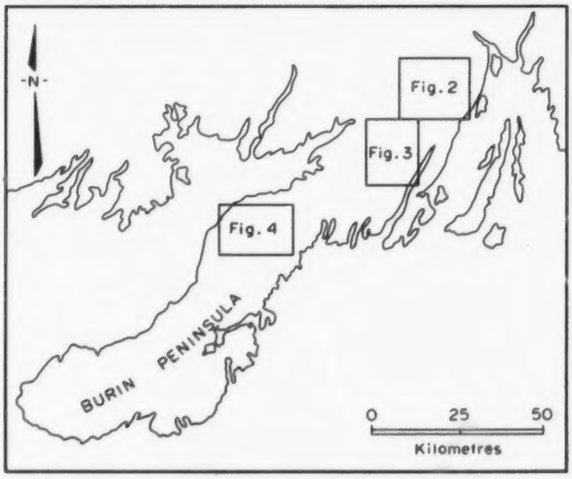

Figure 1: *Burin Peninsula showing location of Figures 2, 3 and 4.*

The specularite showing at Hickey's Pond was examined in the 1930's as a potential source of iron (Dahl, 1934; Bainbridge, 1934). Howland (1938, 1940), in a study which dismissed the deposit's iron potential, noted the presence of alunite ($KAl_3 (SO_4) (OH)_6$). Hussey (1978a,b), with the aid of X-ray diffraction analyses, showed that the 'alunite' was actually the Na-rich analogue, natroalunite. He also recognized pyrophyllite as an important constituent at Hickey's Pond and suggested that the area may have economic potential for precious metals. Other workers in the area have also suggested that the volcanic rocks of the Love Cove Group and associated Precambrian intrusions have a high potential for precious metal mineralization (O'Brien and Taylor, 1979, 1983; Taylor *et al*., 1979).

In 1982, Selco staked the area in the vicinity of Hickey's Pond. The discovery, in 1983, of a quartz-specularite-pyrophyllite-lazulite body 13 km southwest of Hickey's Pond (Tuach, 1984) renewed interest in the area and prompted the initiation of this study. O'Driscoll (1984), in following up Husseys's suggestion of precious metal potential, demonstrated anomalous gold values in rocks collected by Hussey in the Hickey's Pond area. Seven rocks were analyzed for gold with the highest concentration being 850 mg/t, in a banded rock containing specularite, natroalunite, quartz and pyrophyllite.

Work during 1984 (O'Driscoll and Huard, 1984; Huard and O'Driscoll, 1985) defined a north-northeast-trending alteration belt on each side of the Swift Current Granite. These belts are marked by the occurrence of hydrothermal exhalations of chert (± alunite ± specularite ± pyrite), and variably altered volcanic rocks (now sericite ± pyrophyllite ± pyrite schists).

GENERAL GEOLOGY

All of the alteration assemblages are in volcanic rocks of the Late Precambrian Love Cove Group (Figures 2, 3 and 4). Isoclinal folding and flattening of the volcanic rocks have obscured facing criteria and preclude estimation of

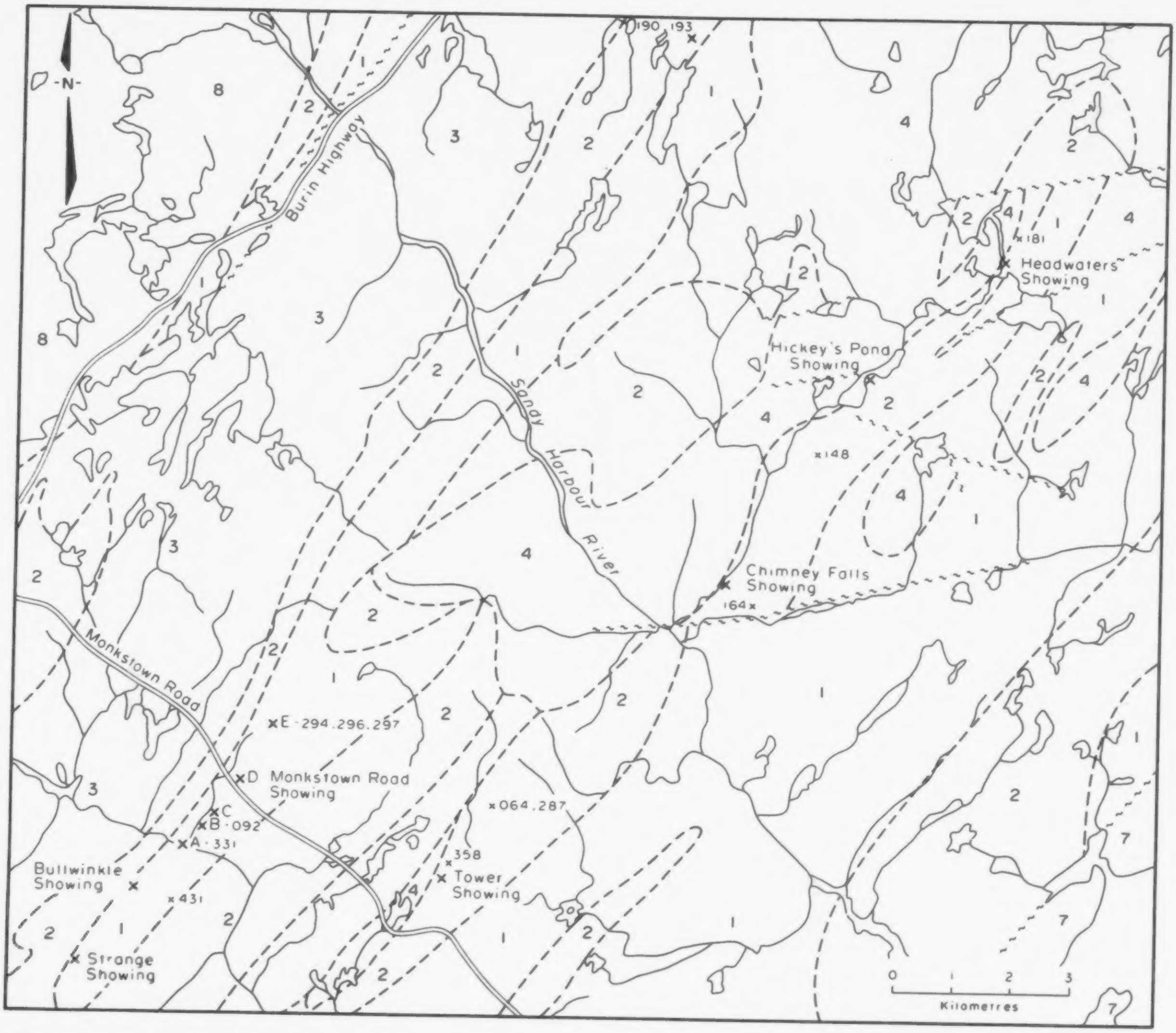
-N-
Burin Highway
Sandy Harbour River
Monkstown Road
190,193
181
Headwaters Showing
Hickey's Pond Showing
148
Chimney Falls Showing
164
E-294.296.297
D Monkstown Road Showing
C
B-092
A-331
064.287
358
Tower Showing
Bullwinkle Showing
431
Strange Showing
0 1 2 3
Kilometres
1
2
3
4
7
8

Figure 2: *General geology of the Eastern and Western alteration belts, showing locations of selected samples and specularite showings.*

stratigraphic thicknesses. Near the Swift Current Granite, mafic flows that are presumed to form the lowermost units of the volcanic sequence are in fault contact (the Paradise Sound Fault) with Cambrian and older clastic sedimentary rocks of the Musgravetown Group, Random Formation and Bonavista Formation to the east. These flows are commonly porphyritic and may include porphyritic intermediate flows. Higher in the sequence, lithic tuffs with a mafic matrix grade into crystal-lithic tuffs, rhyolite flows and welded(?) tuffs. Small-scale interlayering of these units can be observed in the field, indicating this 'stratigraphy' is a simplification of a more complex interlayered sequence. Detailed stratigraphy is not available, due to the discontinuous nature of the members along strike, and the difficulty in distinguishing depositional repetition from structural repetition. The volcanic sequence is overlain conformably (Hussey, 1978a,b) by graywackes and conglomerates of the Sandy Harbour River Formation and equivalent rocks to the southwest (O'Brien and Taylor, 1983; O'Brien *et al.*, 1984). The Swift Current Granite, Cape Roger Mountain Batholith and the Knee granitoids intrude the volcanic and sedimentary sequences.

Age Relationships and Geochronology

The Late Precambrian stratified rocks are a conformable sequence; however, the detailed stratigraphy is complicated by depositional and structural repetition. In general, mafic flows pass upward into mafic lithic tuffs and felsic tuffs, which grade into coarse grained, water-lain, clastic sedimentary rocks. Field relationships between the Swift Current Granite and the Love Cove Group suggest the two are coeval. Although granite dikes intrude the volcanic rocks, granite clasts occur in some tuff beds. These observations can be reconciled if the granite is interpreted as a synvolcanic intrusion.

LEGEND

DEVONIAN

ACKLEY GRANITE

8 Massive, pink, coarse grained, feldspar-megacrystic, biotite granite.

MUSGRAVETOWN GROUP, RANDOM FORMATION AND BONAVISTA FORMATION

7 Green to red sandstone, siltstone and conglomerate; minor mafic flows and tuffs; white quartzite and interbedded sandstone; purple to green slate containing pink limestone nodules.

CAMBRIAN OR EARLIER

SWIFT CURRENT GRANITE (4), CAPE ROGER MOUNTAIN BATHOLITH (5) AND KNEE GRANITOIDS (6)

4,5,6 Medium grained, foliated to massive, hornblende-biotite granite, granodiorite, and syenite.

HADRYNIAN OR EARLIER

LOVE COVE GROUP

3 Green graywacke, arkosic sandstone, and conglomerate.

2 Predominantly felsic pyroclastics and flows. Minor mafic flows and tuffs, and minor mafic dikes.

1 Predominantly mafic flows, tuffs and dikes, including minor intercalated felsic tuffs.

SYMBOLS

sample locality	×
specularite showing	×
geological contact (approximate)	- - -
fault (assumed)	∼∼∼

This interpretation is supported by the geochronologic investigation of Dallmeyer *et al.* (1981). Crystallization dates of 580±20 and 590±30 Ma were obtained for the Swift Current Granite and Love Cove Group volcanic rocks respectively, by U-Pb determinations on zircon fractions. It was concluded that the rocks are comagmatic, and that the granite is subvolcanic.

The Cape Roger Mountain Batholith is petrographically similar to the Swift Current Granite and the two are interpreted to be the same age (O'Brien *et al.*, 1984). The intrusions in the 'Knee' area of the Burin Peninsula are all pretectonic, and are considered to be cogenetic with the main period of intrusive activity that occurred during the Late Proterozoic (O'Brien and Taylor, 1983).

Structure

Most of the volcanic rocks have a well developed, steeply dipping cleavage; most dikes, quartz veins and flow boundaries are parallel to this foliation. Also, clasts in lithic tuffs are flattened in the fabric planes. This hinders positive identification of bedding and determination of younging directions. The cleavage is axial planar to isoclinal folds of quartz veins, and is interpreted to be related to large scale folds as well. A single cleavage-bedding intersection on Paradise River indicates that the beds there are upward facing. Also, clasts are flattened on the cleavage plane and not on the bedding plane, which is at a 30° angle to the cleavage. Dallmeyer *et al.* (1983) dated, by $^{40}Ar/^{39}Ar$ age spectra, sericite that had crystallized on this regional foliation. Two samples from this study area yielded ages of 386 ± 10 Ma and 388 ± 10 Ma. They concluded that the deformation and recrystallization occurred during the Devonian Acadian Orogeny. Locally, the regional foliation was crenulated and folded by the development of a widely spaced strain-slip cleavage.

The regional foliation is locally developed in the granites and is defined by oriented mafic minerals, numerous joint sets, and small faults.

Metamorphism

All rocks in the study areas were regionally metamorphosed at greenschist facies conditions. Assemblages containing various combinations of sericite, chlorite, epidote, quartz, calcite, actinolite and minor biotite have developed syntectonically (Hussey, 1978b; O'Brien and Taylor, 1983). Syn to posttectonic chloritoid occurs in pyrophyllite schists on both sides of the Swift Current Granite. This mineral is common in highly aluminous rocks that have been subjected to greenschist facies metamorphism.

According to O'Brien and Taylor (1983), the effects of thermal metamorphism, varying from albite-epidote to hornblende-hornfels facies, occur throughout the areas adjacent to the Proterozoic granites. Such metamorphism, however, is not evident along the eastern contact of the Swift Current Granite.

DESCRIPTIONS OF SHOWINGS

Eastern Alteration Belt

The Eastern alteration belt as defined by Huard and O'Driscoll (1985) includes three main showings which are in fault contact with the Swift Current Granite to the west (Figure 2). The showing at Chimney Falls is composed of soft quartz-pyrophyllite (± specularite ± chloritoid ± pyrite) schists. Rounded and embayed quartz phenocrysts in the schists attest to the volcanic origin of these highly altered rocks. A 40 cm thick, resistant siliceous zone occurs within the schists. It is fragmental, consisting of clasts of microcrystalline quartz, minor pyrophyllite and minor isolated alunite crystals in a specularite- and quartz-rich matrix. Several rounded quartz phenocrysts indicate that this rock was also of volcanic origin.

The showing at the headwaters of Hickey's Brook consists of quartz-rich, sericite and pyrophyllite schists. Similar rocks occur at the edge of a small pond 500 m to the north-northeast, and in the area between these two points.

The main showing in the Eastern alteration belt is at Hickey's Pond. The showing occurs in a very siliceous resistant body approximately 250 m by 50 m and is elongated in a north-northeast direction. The host rock is typically banded, consisting of layers of various combinations of quartz alunite ± pyrophyllite ± specularite ± pyrite ± rutile. Rutile and pyrophyllite are rarely present in modal proportions greater than 1 percent. Rutile is usually found either as very small rounded crystals concentrated in very fine bands or, less commonly, as small euhedral aggregates of the small crystals. Specularite and pyrite, which are mutually exclusive within bands, can comprise a few percent of the rock, and alunite can reach approximately 35 percent. Very small lithic fragments, now composed predominantly of quartz and alunite, are visible in thin section. These lithic clasts occur rarely as the main component of discrete bands up to 1 cm thick.

The other rock type at Hickey's Pond is fragmental, consisting of quartz-alunite clasts in a specularite-rich matrix. The clasts are usually less than 2 cm long but have widely varying size, size-sorting and shape. The matrix typically contains equal amounts of specularite and quartz with minor alunite, but locally consists of nearly pure specularite. Euhedral, tan-colored aggregates of rutile, up to 2 mm long, occur in the matrix and clasts. The breccias are found in a lenticular, north-northeast-trending zone that is 150 m long and up to 5 m wide.

The showing at Hickey's Pond is bounded on three sides by the pond and on the fourth side by a bog. The rocks immediately to the east-southeast of the bog, approximately 100 m from the showing, are unaltered, felsic, crystal tuffs. No phenocrysts were observed in samples from this showing.

A large showing (referred to here as the Tower showing) similar to the one at Hickey's Pond was discovered along strike 11 km to the south-southwest. It occurs in four resistant mounds separated by narrow bogs. The mounds rise approximately 5 m above the bog and form a straight, north-northeast-striking zone at least 450 m long. It strikes southward into a low ridge of glacial till almost 500 m wide and was not observed to the south of this ridge. It strikes northward into a 500 m wide pond. The showing's contacts in the east and west are covered by bog; however, rocks encountered 25 m toward the east are unaltered felsic crystal tuffs. Toward the west, a narrow zone of pyritiferous, altered, volcanic rocks separates the showing from unaltered granite.

The rocks at the Tower showing are variable assemblages of quartz, alunite, pyrophyllite, specularite, pyrite and rutile. Alunite and specularite are best developed on the western flank of the showing, where dark-gray specularite-rich bands alternate with pink, specularite-free, quartz-alunite rock. Toward the east, gray, pyritiferous, quartz-alunite assemblages pass into massive gray chert.

There are significant differences between the Tower and Hickey's Pond showings. For example, quartz phenocrysts occur in the Tower showing, whereas none have been seen at Hickey's Pond. Lithic fragments, on the other hand, occur sporadically at the Hickey's Pond showing but none have been recognized at the Tower showing. The quartz phenocrysts at the Tower showing demonstrate that the quartz-alunite-specularite assemblage represents an extremely altered volcanic rock. This type of alteration will be discussed later.

Western Alteration Belt

The Western alteration belt as defined by Huard and O'Driscoll (1985) includes five specularite showings which define a north-northeast-trending zone 2.5 km long. Its trace is 5 km west of the Eastern alteration belt, on the west side of the Swift Current Granite (Figure 2).

Where the Monkstown Road crosses the alteration belt, a showing (the Monkstown Road showing) occurs in a swamp approximately 100 m north of the road (Locality D on Figure 2). It is an extremely siliceous, north-trending, elongated body approximately 40 m by 10 m. Most of the outcrop is tan-colored, fragmental, siliceous rock. Fragments are angular and range up to 10 cm across. The matrix is brown quartz, which commonly displays chalcedonic banding (Plate 1). These bands persist for only short distances, on the order of 10 cm, and may represent either fragmented fissure fillings in the subsurface or silica sinter at the surface. Part of the southwest corner of the outcrop is hydrothermally brecciated (Plate 2). An elongated triangular zone, 20 cm long, contains angular fragments of chert 'floating' in a black, specularite-rich matrix. The brecciation passes upward into thin veinlets of specularite. Specularite is also present in syntectonic quartz veins, where coarsely crystalline varieties of quartz and specularite define a vertical lineation on a steep, northwest-dipping, fault plane. Brilliant-blue lazulite occurs in similar quartz-specularite veins throughout the showing.

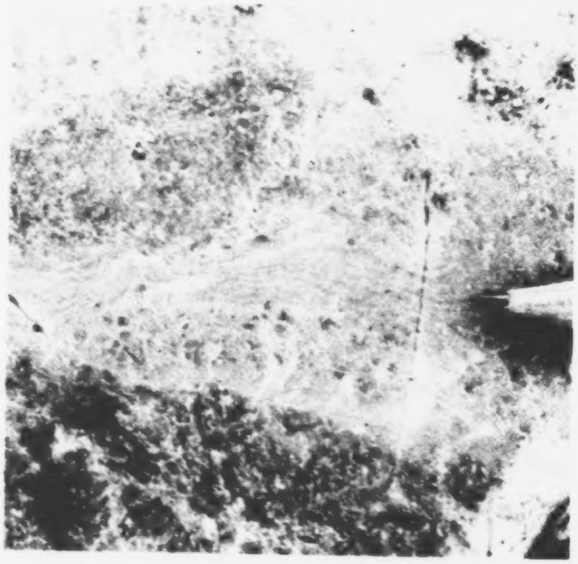

Plate 1: *Chalcedonic banding in fragmental siliceous rock at the Monkstown Road showing.*

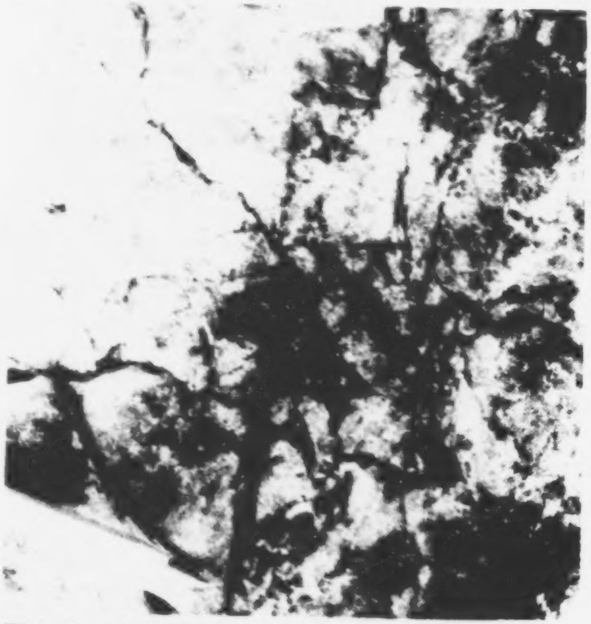

Plate 2: *Hydrothermal breccia at the Monkstown Road showing containing chert fragments in a black, specularite-rich matrix.*

Similar rocks also occur 0.5 km south-southwest of the Monkstown Road showing (Locality C on Figure 2). This is another resistant body surrounded by bog, but it is only 3 m long. Another specularite showing occurs 0.75 km south-southwest of the Monkstown Road showing (Locality B on Figure 2). Black bands of quartz-specularite-chloritoid-rutile alternate with white to tan chert. No alunite was observed in the rocks at Localities B, C and D.

Locality E, 2.25 km north-northeast of the Monkstown Road showing, consists mostly of scattered outcrops of gray, extremely siliceous rock in a north-northeast-trending, 200 m by 40 m zone. On the showing's western edge, pink alunite-rich rocks containing black specularite-rich bands occur. Pyrophyllite and chloritoid also occur at this showing. Chloritoid, which occurs as small crystals in the schistose pyrophyllite-rich zones, appear to be porphyroblasts.

Siliceous, spheroidal nodules comprise half the rock at the southernmost outcrop of this showing (Plate 3). Concentric 'shells' can be observed in the outcrop. In thin section, they are seen to be shells of either extremely fine grained recrystallized quartz, or quartz and alunite surrounding coarse grained quartz nucleii. The 'matrix' around these nodules is a much coarser grained assemblage of quartz, alunite, specularite and pyrophyllite.

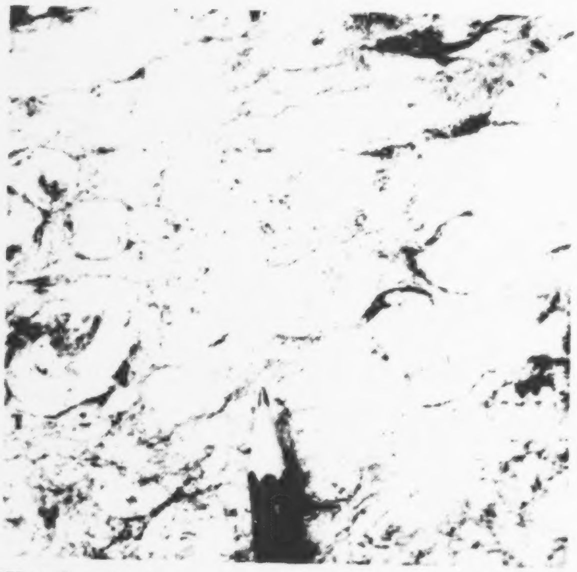

Plate 3: *Siliceous, spheroidal nodules containing concentric layers of finely recrystallized quartz and quartz-alunite around coarse grained quartz nucleii (Locality E on Figure 2).*

The showing at Locality A is a resistant, circular, siliceous mound 30 m in diameter that rises approximately 5 m above the surrounding area. It is predominantly gray, siliceous rock, but can also include alunite, pyrite, specularite and pyrophyllite. These rocks form the northern bank of Paradise River at this locality. They continue south under the river as a shallow ledge and also outcrop on the southern bank.

A major specularite showing (referred to here as the Bullwinkle showing) was found in 1985 along strike from the Western alteration belt. It is centred 1 km south-southwest of the showing at Locality A, and is approximately 900 m long. The Bullwinkle showing is defined by the occurrence of resistant rocks composed of varying proportions of quartz, alunite, specularite, pyrite, pyrophyllite and rutile. These rocks are disposed in two parallel, northeast-trending zones, 175 m apart. The outcrops in each zone are approximately 30 m wide at their widest point, but taper off at both ends.

Specularite occurs with quartz and alunite as black bands within the pink quartz-alunite rock. Pyritiferous quartz-alunite rocks are volumetrically less important. They are absent at the northern end of the eastern outcrop zone but account for half of the rock in the southern end of this zone. Two outcrops of specularite-rich breccia occur 25 m apart in the centre of the eastern outcrop zone. Some of the breccia is similar to that at Hickey's Pond, i.e., it consists of angular quartz-alunite-rutile clasts in a matrix of specularite-quartz-alunite-rutile. At the Bullwinkle showing, however, the breccia is more flattened and stretched. A quartz phenocryst, the only one observed at this showing, occurs in a quartz-specularite fragment in this breccia.

Another type of breccia found at the Bullwinkle showing is unlike any from Hickey's Pond. It contains subrounded, unsorted quartz-alunite-specularite fragments of varying color, texture and composition in a matrix of quartz, specularite and alunite.

At the northern end of the eastern outcrop zone, rounded purple fragments up to 10 cm long occur in a band that parallels the compositional banding in the quartz-alunite specularite rock (Plate 4). These fragments are themselves fragmental, consisting of quartz-specularite-rutile fragments in a stockwork of quartz and specularite. The rutile is especially well developed in these fragments as coarse euhedra up to 2 mm long.

Plate 4: *Breccia fragments in a band that parallels compositional banding; dark band under fragments is specularite rich. Field of view is 20 cm (Bullwinkle showing).*

The Bullwinkle showing is bounded to the east and west by mafic volcanic rocks. The rocks on the eastern side are pyritiferous, and grade into unaltered mafic rocks approximately 200 m east of the showing.

A specularite showing (referred to here as the Strange showing) was discovered 1.5 km south-southwest of the centre of the Bullwinkle showing. It is a small low outcrop, only 3 m across, composed of black, vitreous, siliceous rock. The rock is intensely flattened and consists of fine grained quartz and wispy bands of recrystallized specularite that occur parallel to the foliation. Minor rutile(?) forms small crystal aggregates oriented parallel to the fabric. No alunite was observed in this rock. Within a metre of this rock, across a probable intrusive contact, there is a bright-pink rhyolite dike containing, deformed blebs of pyrite.

Cape Roger Mountain Batholith Area

The Eastern alteration belt in the Swift Current Granite area is coincident with the fault contact between the granite and volcanic rocks. A southern extrapolation of this contact occurs along the eastern margin of the Cape Roger Mountain Batholith, but it is unexposed (Figure 3). However, a zone of alteration 5 km long parallels it, 1 km to the east. This zone is characterized by sericite schist, pyritiferous sericite schist, and two occurrences of gray chert boulders. A small outcrop of gray chert occurs in this belt at UTM grid reference 811691 in the Terrenceville (1M/10) map area (Figure 3; sample 375). Several kilometres to the north-northeast (sample 383), specularite occurs in very small veinlets and as disseminations in rhyolites.

Burin Peninsula Knee Area

Pyritiferous chert, which may be a sinter, occurs as discontinuous outcrops in a zone 700 m long at UTM grid reference 520544 in the Baine Harbour (1M/7) map area (Figure 4; samples 411, 413). The northernmost part of the zone is parallel to the regional northeast-trending cleavage. However, toward the south, the chert bodies are gradually rotated into, and then parallel for several hundred metres, an east-southeast-striking shear zone (mapped by O'Brien and Taylor, 1983). Pyritiferous sericite schist, and pyritiferous silicified rock are found in several localities near the margins of the Knee granitoids (Figure 4).

PETROGENESIS

The rocks at Hickey's Pond and the other showings do not resemble volcanic rocks in mineralogy or texture. Nor is there a continuum between these resistant siliceous rocks and the surrounding volcanic rocks. However, at Chimney Falls, the auriferous mineralization is exclusively an alteration feature of easily recognized volcanic rocks. The quartz phenocrysts readily seen in thin sections of the quartz-pyrophyllite (± specularite ± pyrite) schists prove this. This showing, however, is not representative. The other showings are much more siliceous and resistant, unlike the easily eroded rocks at Chimney Falls, and they are characterized by an abundance of alunite.

The formation of alunite is regarded as a near surface phenomenon involving 3 steps: 1) boiling of an ascending hydrothermal fluid and partitioning of H_2S into the vapour

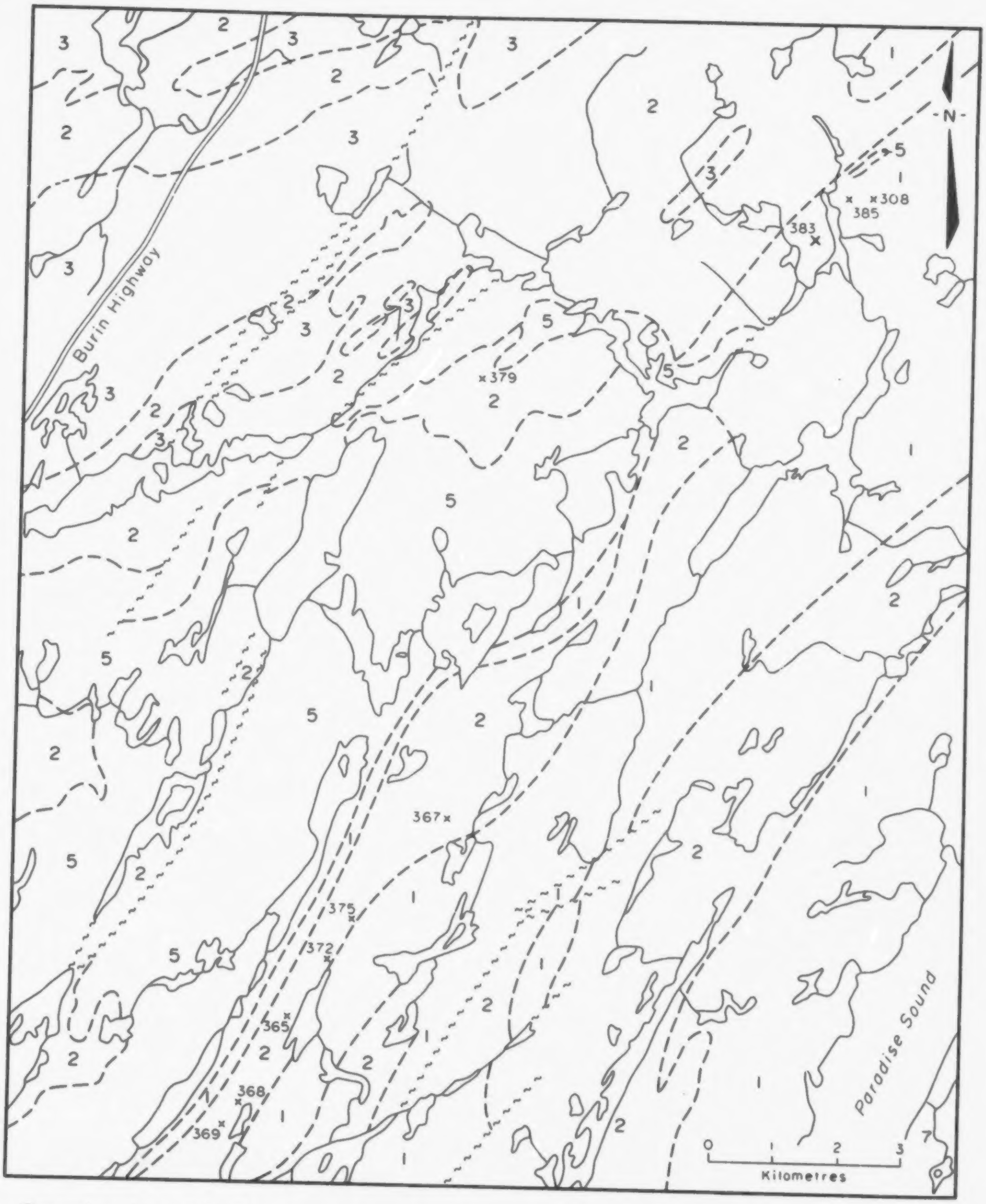

Figure 3: *General geology of the Cape Roger Mountain Batholith area (modified from O'Brien et al., 1984), showing locations of selected samples. See Figure 2 for Legend.*

phase, 2) upward transport of the vapour followed by cooling, condensation and oxidation to form H_2SO_4-rich waters, and 3) interaction of these waters with the surrounding shallow rocks (Raymahashay, 1968; Henley and Ellis, 1983; Cunningham *et al.*, 1984). Cunningham *et al.* (1984) suggest that the oxidation required to produce the alunite assemblages took place above the water table. Raymahashay (1968) described near-surface alunitization and the formation of alunite as a direct chemical precipitate at an acid hot spring.

Thus, alunite is an indicator of the highest part of an epithermal system, either as an alteration product or as a surficial precipitate. This is an important consideration concerning the showings on the Burin Peninsula—are they chemical precipitates or alteration products? The fact that alunite can form in either situation prevents its occurrence from resolving this question. The other minerals found at these showings will now be considered with this question in mind.

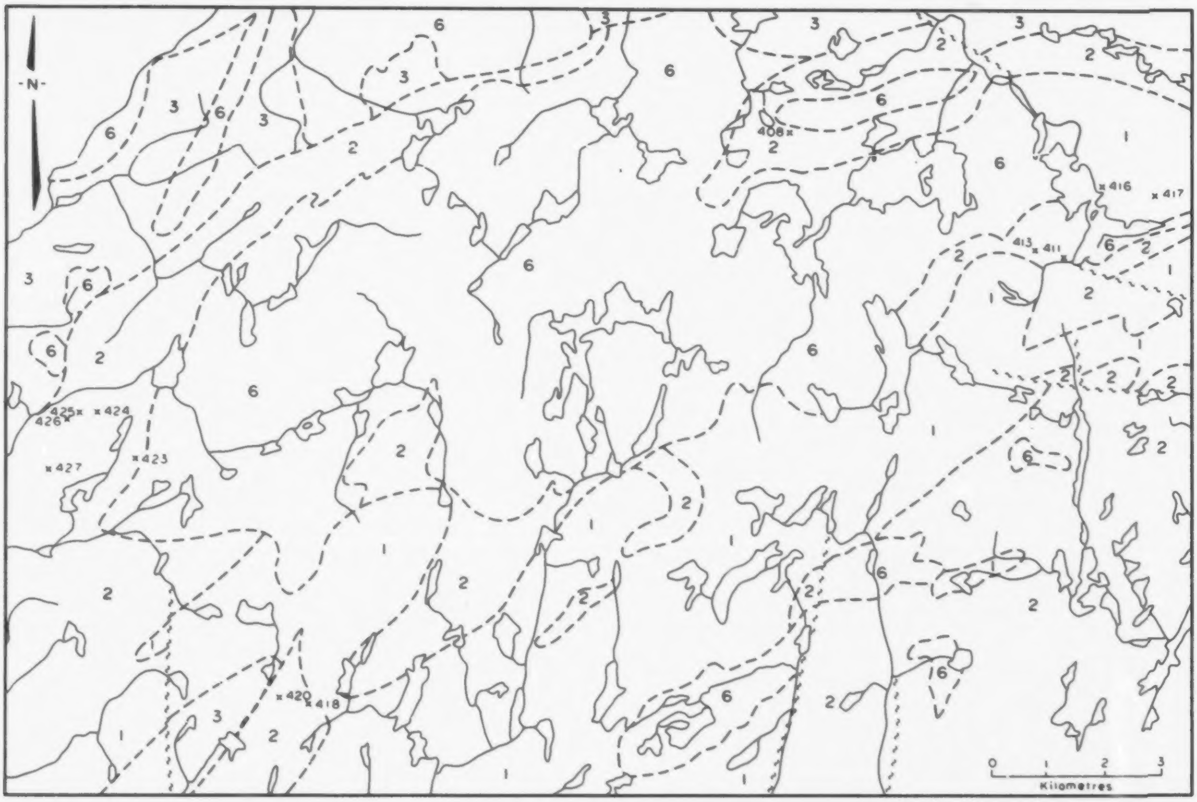

Figure 4: *General geology of the Burin Peninsula Knee area (after O'Brien and Taylor, 1983), showing locations of selected samples. See Figure 2 for Legend.*

Quartz is the most commonly precipitated mineral at hot springs, where it usually forms amorphous masses. The quartz in the Burin Peninsula showings is microcrystalline, a texture easily attributed to recrystallization of an originally amorphous silica during subsequent deformation and metamorphism. Silica is also abundant, however, in acid-leached rocks.

Pyrophyllite and kaolinite are common products of acid leaching. Knight (1977) showed that pyrophyllite can be in equilibrium with a very low temperature fluid if it is supersaturated with silica. Otherwise, kaolinite will be the stable aluminous phase. Raymahashay (1968) describes kaolinite in several hot springs. Preliminary X-ray diffraction studies of clay minerals from the Hickey's Pond and Bullwinkle showings reveal them to be dominantly pyrophyllite. However, small peaks which correspond to kaolinite were also recorded, indicating a few percent kaolinite in the clays. This can be accounted for by postulating a metamorphic reaction in which kaolinite was almost completely replaced by pyrophyllite.

Specularite was reported by Cunningham *et al.* (1984) in alunitized Tertiary volcanic rocks near Marysvale, Utah. They also described its occurrence in the sinters overlying the alteration. Rutile could represent the residue of an altered titanium-bearing phase in an altered volcanic rock. On the other hand, anatase (another polymorph of TiO_2) is described by Buchanan (1981) in sinters that cap epithermal systems. Finally, the occurrence of pyrite is too ubiquitous to differentiate between the two possible origins of these rocks.

Thus, the mineral assemblage quartz-alunite-specularite-pyrite-pyrophyllite-rutile, in light of the deformation and metamorphism undergone by these rocks, cannot be used to distinguish whether these are sinters or altered volcanic rocks. Other lines of evidence are needed. The best evidence is the occurrence of quartz phenocrysts in the quartz-alunite-specularite rocks on the west side of the Tower showing, which clearly shows that these are intensely altered felsic volcanic rocks. The massive cherty rocks a few metres to the east may represent a silica sinter. Although quartz phenocrysts were not observed at Hickey's Pond, and only one was seen at the Bullwinkle showing, this does not preclude these rocks from having a volcanic origin. There are, however, several lines of evidence that are not compatible with an alteration model.

Pyrite and specularite are mutually exclusive in centimetre-scale bands that persist for several metres. This mineralogical banding is best developed at Hickey's Pond, where the bands maintain their identity even though they are isoclinally folded; the banding is therefore pretectonic. It is interpreted to be a primary chemical banding, reflecting changing oxygen and sulfur fugacities in the fluid from which these minerals precipitated. This interpretation is supported by the occurrence of specularite-bearing fragments in the pyritiferous rocks.

The lithic fragments at the Hickey's Pond and the Bullwinkle showings support a surficial origin for these rocks, as opposed to an alteration model. The fragments at Hickey's Pond are light gray, rounded, very slightly elongate and up to 3 mm in length. The light gray material forms a framework in an originally, highly porous (approximately 70 percent) rock; the 'pores' are circular to slightly ellipsoidal, and are now filled with quartz and minor alunite (Plate 5). Texturally these fragments are pumice, and their existence is strong evidence against an alteration model, as they should be the most easily altered component of any rock. Their incorporation is easily explained, either by erosion and transport from nearby ash falls, which are common in the study area, or by direct eruption into an active hot spring in which the Hickey's Pond showing was forming. Elsewhere at the Hickey's Pond showing, pumice occurs as more intensely deformed fragments.

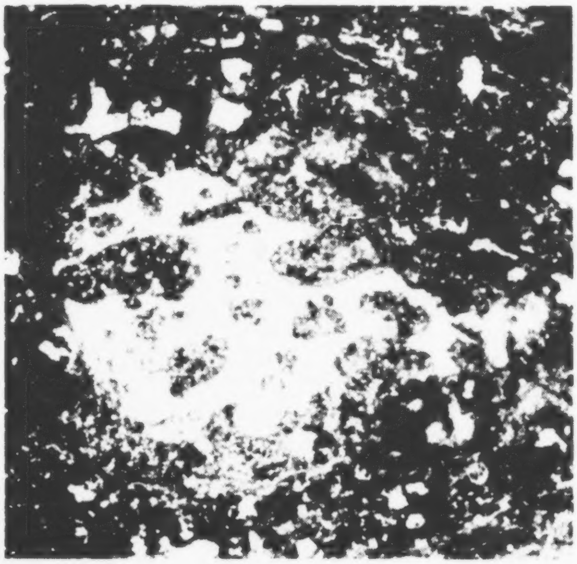

Plate 5: *Light-colored, rounded, lithic fragment containing circular to ellipsoidal 'pores' filled with quartz and minor alunite (Hickey's Pond showing). The field of view is approximately 4 mm.*

A different type of lithic fragment, occurs at the Bullwinkle showing. These fragments are specularite-rich breccias and their presence not only argues against an alteration model, but has strong implications to be discussed below, for the origin of these breccias.

The concentrically shelled, siliceous nodules observed at Locality E (Plate 3) are interpreted to be geyserite eggs, as described by Rinehart (1980) and Spence *et al.* (1980). This interpretation can only be reconciled with a surficial origin for this quartz-alunite-specularite-pyrophyllite showing.

Specularite-Rich Breccias

Fragmental rocks with specularite-rich matrices occur at the Chimney Falls, Hickey's Pond, Bullwinkle and Strange showings. The specularite gives these rocks a very dark color which commonly conceals their fragmental nature in outcrop. The breccias might be interpreted as 1) fault breccias which were later cemented with specularite-quartz-alunite-rutile, 2) hydrothermal breccias occurring at the place of brecciation in either volcanic rock or sinter, and 3) aprons of hydrothermal explosion breccia disposed around the orifice of a vent in an active hot spring. Cunningham *et al.* (1984) describe hydrothermal breccias with hematite-bearing matrices in the sinters near Marysvale, Utah. This might be a modern analogue to (3) above.

Observations relevant to the origin of the breccias are summarized below:

1) The breccias at Chimney Falls are in contact with altered volcanic rock. They contain quartz phenocrysts that have slightly undulatory extinction but are not seriously strained.

2) Demonstrable fault gouge at Hickey's Pond is confined to zones less than 5 cm thick. It is schistose, pyrophyllite rich, and texturally and mineralogically unlike the breccias.

3) Breccias at Hickey's Pond define an elongate lenticular belt with maximum dimensions of 150 m by 5 m that parallels the regional structural trend and the presumed fault contact with the Swift Current Granite to the west.

4) Incipient gas brecciation occurs at the breccia pipe at the Monkstown Road showing.

5) Clasts of specularite-rich hydrothermal breccia are incorporated in the sinters at the Bullwinkle showing.

6) Axial planes of folds in banded rock at Hickey's Pond continue into the breccias as joints. The breccias are therefore pretectonic.

7) Rutile occurs as large euhedral 'crystals' (leucoxenes?) in the breccias at Hickey's Pond and the Tower showing. In obviously tectonically deformed rocks, e.g., the Strange showing and some banded rocks at any of the major showings, the rutile can be seen in various stages of deformation, culminating in wispy bands of very small, rounded crystals.

8) Some of the breccias at the Bullwinkle showing are polylithic.

9) The fragment size decreases and the size-sorting improves away from the centre, toward both ends of the breccia zone at Hickey's Pond.

10) The main breccia zone is conformable with the banding at Hickey's Pond, although narrow bodies of breccia show disconformable relationships in places.

11) All the breccias have a variably developed tectonic fabric.

The breccia at Chimney Falls is clearly a hydrothermal stockwork breccia in altered volcanic rocks. The interpretation that the breccias at Hickey's Pond and the Bullwinkle showing are hydrothermal explosion-breccia aprons is supported by their shape (3), sedimentary features (9) and contacts (10). The few disconformable contacts observed could represent subsurface intrusive breccias associated with the main breccia. Supporting the idea that these are tectonic breccias is their elongate shape (3) and their tectonic fabric (11). However, their dissimilarity with known fault-related rocks at Hickey's Pond (2), their rare polylithic nature (8), their variable and commonly minor deformation (1, 7), their pretectonic origin (6), and their pre to syndepositional relationship with the hot springs (5) mitigate strongly against a tectonic origin for these breccias. Nor can they be considered *in situ* breccias as their shape (3), sedimentary features (9), and most of the contacts (10, bearing in mind the intrusive breccias) are not consistent with this model.

Conclusion

Various parts of the highest level of an epithermal system are represented by these rocks. The stockwork breccia in volcanic rocks at Chimney Falls is the deepest part, representing the ascent of hydrothermal fluid. This stockwork is surrounded by alunitized, pyrophyllitized (originally kaolinized?) and sericitized zones, which commonly contain specularite and pyrite. Higher in the system, widespread alunitization, silicification and specularitization of volcanic rocks occurred, such as that at the Tower showing. Finally, the fluids reached the surface and precipitated the showings described here. Geysers were active near some of these hot springs. Breccia aprons formed explosively, were eroded and incorporated as clasts, along with other clastic detritus, in the thickening sinter. Eventually, the sinters were buried by volcanic rocks.

GOLD GEOCHEMISTRY

Approximately 250 whole-rock samples were analysed for gold in the course of this study. They represent various stages of alteration in the volcanic rocks and the different hot spring related assemblages. Table 1 shows selected analyses.

Table 1. Selected Gold Analyses

Sample Number	Description	mg/t
	SWIFT CURRENT GRANITE AREA (FIGURE 2)	
064	pyritiferous quartz-sericite schist	10
092	specularite-rich chert	5
148	quartz-sericite schist	5
164	pyritiferous quartz-sericite schist	5
181	quartz-pyrophyllite schist	100
190	chlorite-sericite schist	5
193	quartz vein containing minor specularite	5
287	pyritiferous, silicified, crystal tuff	5
294	quartz-pyrophyllite-specularite schist	5
296	banded alunite-specularite-rich chert	5
297	siliceous rock containing geyserite eggs	5
331	banded alunite-specularite-rich chert	5
358	pyritiferous quartz-sericite schist	5
431	pyritiferous, silicified, crystal tuff	1
Headwaters Showing		
144	pyritiferous quartz-sericite-pyrophyllite schist	10
335	quartz-pyrophyllite schist	15
Hickey's Pond Showing		
135	banded alunite-specularite-rich chert	350
170	pyritiferous chert	2530
227	alunite-rich chert	1450
232	alunite-specularite-rich chert	170
235	specularite-rich chert breccia	5400
254	specularite-rich chert breccia	45
255	specularite-rich chert breccia	4710
341	specularite-rich chert breccia	4950

Table 1 (*continued*)

Chimney Falls Showing		
154	quartz-pyrophyllite-specularite schist	5
156	specularite-rich stockwork breccia	335
161	quartz-pyrophyllite-specularite schist	45
Tower Showing		
271	gray pyritiferous chert	30
276	alunite-specularite-rich rock	5
283	quartz-alunite-specularite-pyrophyllite rock	5
428	pyritiferous chert containing minor pyrophyllite	36
Monkstown Road Showing		
094	quartz-pyrophyllite schist	5
096	specularite-rich chert	5
101	pyritiferous quartz-sericite schist	75
Bullwinkle Showing		
311	banded specularite-rich chert	5
316	banded alunite-specularite-rich chert	5
321	specularite-rich chert breccia	5
330	pyritiferous chert	45
435	pyritiferous chert	47
436	banded alunite-specularite-rich chert	121
443	pyritiferous chert	110
Strange Showing		
327	intensely sheared, specularite-rich, chert breccia	800
328	pyritiferous rhyolite dike	5
440	intensely sheared, specularite-rich, chert breccia	276
441	intensely sheared, specularite-rich, chert breccia	813
	CAPE ROGER MOUNTAIN BATHOLITH AREA (FIGURE 3)	
308	pyritiferous quartz-sericite schist	5
365	pyritiferous, silicified, crystal tuff	1
367	pyritiferous quartz-sericite schist	1
368	pyritiferous quartz-sericite schist	2
369	pyritiferous quartz-sericite schist	1
372	pyritiferous, silicified, crystal tuff	
375	gray chert and minor pyrophyllite	1
379	crystal tuff containing minor pyrite	1
383	rhyolite containing blebs of specularite	1
385	pyritiferous quartz-sericite schist	14
	KNEE GRANITOIDS AREA (FIGURE 4)	
408	pyritiferous quartz-sericite schist	4
411	pyritiferous chert	1
413	pyritiferous chert	1
416	pyritiferous sericite schist	3
417	pyritiferous chlorite-sericite schist	2
418	pyritiferous silicified rock from boulder	73
420	pyritiferous silicified rock	8
423	pyritiferous, silicified, crystal tuff	1
424	pyritiferous quartz-sericite schist	15
425	quartz-sericite schist	2
426	pyritiferous silicified rock	1
427	pyritiferous quartz-sericite schist	2

The following observations concerning gold mineralization can be made:

1) The gold concentrations in a given rock type can vary significantly within and between showings.
2) The showing at Hickey's Pond has the highest gold numbers.
3) The breccias at Hickey's Pond return the highest analyses, but they are not consistently high.
4) At Chimney Falls, gold is especially high in the stockwork breccia (335 mg/t in sample 156) but falls off abruptly in the pyrophyllitized volcanic rocks.
5) At the Tower and Bullwinkle showings, gold is more commonly found in pyritiferous rocks than specularite-bearing ones.
6) The specularite-rich breccias of the Bullwinkle showing are barren.
7) The Strange showing returns the highest gold concentrations (813 mg/t) outside the Hickey's Pond area.
8) The only gold detected at Locality E (5 mg/t in sample 297) from 8 samples taken was in the rock composed of geyserite eggs.
9) With the exception of the Chimney Falls showing, the various assemblages of altered volcanic rocks contain less than 100 mg/t gold. When all the data on these rocks are considered, those around the western contact of the Knee granitoids give (proportionally) the largest number of 'kicks' and one of the largest assays (73 mg/t in sample 418).

Preliminary microanalyses at Memorial University have revealed that native gold with very minor silver occurs as grains up to 0.03 mm across in the specularite in the breccia matrices. Gold telluride occurs within pyrite in sample 170. Also observed were compounds of uncertain mineralogy containing various combinations of Cu, Ag, Au, As, Sb, Bi, S, Se and Te. This suite of elements is characteristically related to gold in the epithermal environment (Boyle, 1979).

Discussion

Perhaps more surprising than the apparently low concentrations of gold at the Tower and Bullwinkle showings is the high concentration of gold at Hickey's Pond. The 'precious metal horizon' in epithermal systems has a lower limit marked at the depth of boiling, and an upper limit marked by the highest upward movement of the precious metals. This upper limit is often hundreds of metres below the surface (Buchanan, 1981). Occurrences of gold in sinters, such as those at the Broadlands and Waiotapu geothermal fields in New Zealand, are uncommon (Weissberg, 1969). There, however, the sinters contain up to 85,000 mg/t gold. These auriferous sinters are precipitating from waters with temperatures ranging from 75° C to 95° C and pH's from 5.7 to 7.0. A much different type of water precipitating a different type of sinter occurs at Frying Pan Lake, Waimangu, New Zealand. The water is cooler (67° C), has a lower pH (3.8), and has over twice the sulfate ion concentration as the other waters. No gold was detected in this sinter. However, it has unusually high W, P, and As, as well as approximately 10 percent Fe_2O_3 (Weissberg, 1969).

This 'barren' sinter described by Weissberg (1969) is analogous to that at the Bullwinkle showing in that it is iron-rich and precipitated from an acid-sulfate solution. The pH of the water is critical in that condensed, oxidized, H_2S-rich vapour could not have transported gold but would have a low pH. The importance of the low-pH assemblage in a sinter is that it points to the precipitation of precious metals at depth, where boiling occurred. The gold at Hickey's Pond might be the result of very high-level boiling and the direct discharge of some of the boiling fluid into a hot spring dominated by condensed, oxidized H_2S-rich vapour. The particularly gold-rich breccias at Hickey's Pond may attest to this boiling. Although breccias are present at the Bullwinkle showing, they are by volume much less significant than those at Hickey's Pond. This fact, coupled with the polylithic nature of the breccias (including fragments of altered volcanic rock), may point to boiling at a deeper level than that exposed at Hickey's Pond, and the precipitation of precious metals at this level.

CONCLUSIONS

Gold is associated with sinters, high-level specularite and alunite-bearing stockworks, and to a lesser extent, variably altered volcanic rocks on the northern Burin Peninsula. The large, siliceous, resistant sinters are the most easily located parts of the ancient hydrothermal systems that acted on the accumulating volcanic pile. Even so, two of the largest sinters, situated very near a road, were only discovered during the 1985 field season. Using the sinters as starting points, exploration for gold must consider the underlying parts of the hydrothermal system. These will not have the marked surface expression of the sinters, but may well be located with the aid of their anticipated geochemical signatures.

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Our condolences are extended to the moose family that lost one of its members during the course of this field study.

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GNEISS-ANORTHOSITE-GRANITE RELATIONSHIPS IN THE ANAKTALIK BROOK-KOGALUK RIVER AREA (NTS 14D/1, 8), LABRADOR

B. Ryan and D. Lee
Labrador Mapping Section

ABSTRACT

Granulite and amphibolite facies gneisses of the Archean Nain Province and the Early Proterozoic Churchill Province are intruded by Middle Proterozoic plutons of gabbroid, intermediate and granitoid compositions. Contact aureoles are variably developed, the most widely recognized transformation being a pyroxene hornfels assemblage developed in a Churchill Province, granulite facies, garnetiferous gneiss south and east of Makhavinekh Lake. Gabbroic rocks occur as isolated rafts in younger rocks in the Kogaluk River area, but constitute a large coherent body in the northern half of the project area. Intermediate plutons form irregular intrusive bodies in anorthosite north of Trout Pond, but constitute a flat-lying sheet south of Makhavinekh Lake. Rapakivi granite forms an ovoidal, steep-walled, flat-topped pluton between Makhavinekh Lake and Anaktalik Brook. Field relationships suggest co-existence of gabbroid, intermediate and granitoid compositions. Minerals of economic importance are limited to isolated small occurrences of labradorite in the gabbroids, and graphitic and pyritic gossan zones in the metasedimentary rocks.

INTRODUCTION

The discovery in 1979 along the Quebec-Labrador border, approximately 100 km west of Nain, of a small 1.26 Ga pluton of peralkaline granite (Lac Brisson or Strange Lake pluton) unusually enriched in REE, zirconium and beryllium (Currie, 1985, Miller, 1985) has opened up the possibility that similar felsic rocks may occur within parts of the plutonic complexes of the Nain area, currently assigned to the 1.45 Ga Elsonian event. With the potential for such a discovery, a five-year project has been initiated to survey a corridor between coastal Labrador near Nain and the Quebec-Labrador boundary near the Strange Lake pluton (Figure 1). This project corridor is adjacent to a similar east-west transect of the plutonic complexes of central Labrador conducted by J. Hill between 1977-81 (Hill, 1982) in which the Flowers River peralkaline complex was discovered in 1973 (Collerson *et al.*, 1974).

Previous Work

The northern and southeastern parts of the 1985 project area were ground traversed by the late E.P. Wheeler during his pioneering investigations of the 'anorthosite-adamellite' suite of the Nain area, which began in 1926 (cf. Wheeler, 1955; 1974). The only other mapping in the project area is included in the 1:250,000 reconnaissance map of Taylor (1977).

Present Study

The current program aims at re-evaluating the plutonic rocks that occupy the southern half of NTS sheet 14D and the eastern fringe of 24A (Figure 1). The project corridor is well exposed in the east, but heavily covered by glacial overburden in the west. Mapping is being carried out with the aim of producing a final compilation sheet at 1:100,000 scale at the end of the project, and preliminary 1:50,000 maps in the spring following each field season. A preliminary 1:100,000 scale compilation map for the 1985 study area (Ryan and Lee, 1985) is presently available.

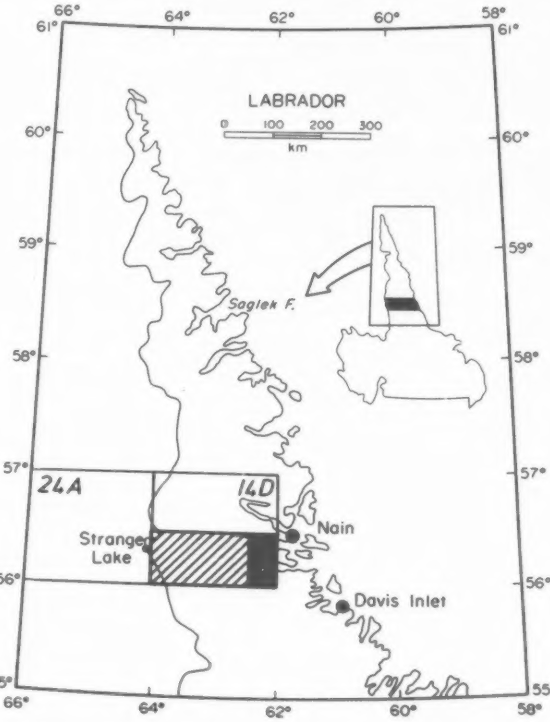
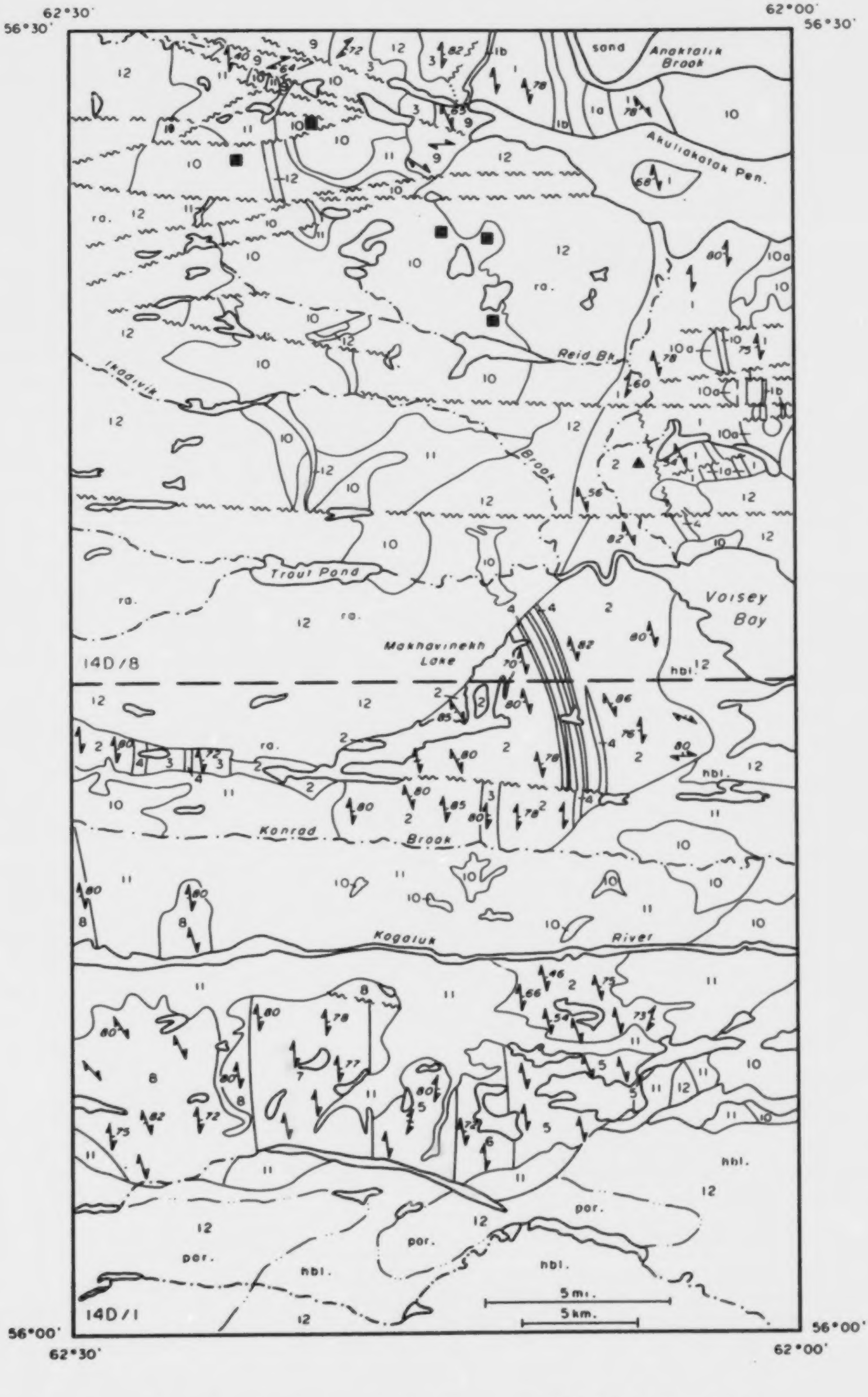


Figure 1: *Location of Nain-Strange Lake project corridor. Area outlined in black is shown in Figure 2.*

This project is a contribution to the Canada-Newfoundland Mineral Development Agreement, 1984-1989


62°30'
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sand
Anaktalik Brook
Akuliakatak Pen.
Reid Bk.
Ikadlivik
Brook
Trout Pond
Voisey Bay
Makhavinekh Lake
14D/8
Konrad Brook
Kogaluk River
14D/1
5 mi.
5 km.
56°00'
62°30'
56°00'
62°00'

Figure 2: *Geological map of the Anaktalik Brook - Kogaluk River area (NTS 14D/1, 8), Labrador.*

LEGEND AND KEY

PROTEROZOIC

Intrusive Rocks

12 Granitic rocks; hbl. = hornblende+clinopyroxene+olivine quartz monzonite and related porphyry (por.); ra. = rapakivi granite.

11 Gabbro, monzogabbro, quartz monzonite.

10 Anorthosite-gabbro-troctolite; 10a, border zone ultramafic rocks.

ARCHEAN AND/OR PROTEROZOIC

Churchill Province

8 Undivided gneisses including augen gneiss and pink granitic gneiss.

6 White granitic gneiss.

4 Metasedimentary gneiss.

2 Garnet-quartz-feldspar gneiss (mylonitic).

9 Cordierite-rich granulite (paragranulite).

7 White, silicious, augen gneiss, locally garnet bearing.

5 Gray biotite gneiss.

3 Hypersthene tonalite gneiss.

ARCHEAN

Nain Province

1 Undivided, banded, gray gneiss and amphibolite, 1a, meta-anorthosite and metaleucogabbro; 1b, paragneiss and amphibolite.

Geological boundary : defined, assumed / ⋰

Gneissic foliation : inclined, vertical ⁄ ⁄

Faults: ∿∿ ∿∿

Labradorite occurrence ■

Pyritic gossan ▲

An account of initial field investigations of the eastern part (14D/1, 8) of the project corridor is presented below. The map area comprises a variety of Archean and Lower Proterozoic gneisses that are intruded by middle Proterozoic plutons; the plutonic rocks range in composition from ultramafic to silicic. Narrow dikes of diabase post-date the plutons; these are rare and are not described here.

GENERAL GEOLOGY

Gneisses

Regionally metamorphosed rocks crop out along the northern and eastern fringes of 14D/8 and in the northern and central parts of 14D/1 (Figure 2). Following Taylor (1977), some of these gneisses are assigned as Archaean (Nain Province) and others as Lower Proterozoic (Churchill Province). These subdivisions are believed valid, based on comparison of the gneisses here with those of the Nain and Churchill provinces of northern Labrador, where age relationships are more clearly understood (Ryan *et al.*, 1983; 1984). The contact between the two provinces in the study area is obscured by expanses of glacial drift except along the northern fringe of the area (Ryan and Lee, 1985). There (west of Akuliakatak Peninsula) the contact corresponds with a small valley, assumed to be the trace of a fault, and separates a highland area of homogeneous enderbitic gneiss from a topographically lower area of amphibolite facies migmatite. The apparently sharp and narrow character of the junction in this region, however, is in strong contrast to that in northern Labrador where it is expressed as a broad zone marked by a major fault or series of faults containing fault gouge and breccia, and mylonite and pseudotachylite.

Nain Province (Archean) Gneisses. Metamorphic rocks considered to be Archean in age outcrop in an arcuate band stretching from Akuliakatak Peninsula southward to Voisey Bay (Figure 2). In many respects they resemble the early Archean rocks of northern Labrador (cf. Bridgwater *et al.*, 1975; Collerson and Bridgwater, 1979) but it is too early to make direct comparisons at this stage of investigation. They comprise a variety of quartzofeldspathic (granitic) gneisses containing mafic gneiss schlieren and pods, metasedimentary and mafic gneiss belts of supracrustal origin, and foliated meta-anorthosite and metagabbro.

By far the most abundant rocks of the Nain Province are gray to pink weathering, tonalitic to granitic, well banded gneisses believed to be of igneous parentage (Unit 1). In outcrop, these locally contain isolated inclusions of ultramafic, mafic and metasedimentary rocks, and more continuous (although also podiform) mafic layers (Plate 1). Previous investigations of similar gneiss terranes (Ryan *et al.*, 1983, 1984) suggest that these various inclusions and rectilinear mafic units have been derived from original rafts and dikes respectively in the igneous precursor to the gneisses. However, nowhere has any discordance been observed between the rectilinear units and a gneissic layering, which would substantiate the suggestion of the mafic units being originally dikes. Deformation has imparted a fabric to the gneisses which varies from a coarse banding to a finely laminated schistosity in straight belts; a good example of the latter is present on the eastern tip of the island south of the Akuliakatak Peninsula. The whole complex is migmatized by a network of granitic stringers and dikes, some of which are folded and synkinematic with the regional deformation, whereas others are planar and posttectonic.

Plate 1: *Nain Province gneisses. Gray, biotite gneiss (Unit 1), containing amphibolite layers probably derived from basic dikes; at least two generations of granitic veining is present. Coastal exposure north of Reid Brook.*

Interlayered with the quartzofeldspathic gneisses are supracrustal belts (subunit 1b) of layered mafic gneiss, metasedimentary gneiss, and meta-anorthosite (subunit 1a). Mafic gneisses (amphibolites and mafic granulites) are layered on a 1 cm to 10 cm scale, and are migmatized in a manner analogous to the surrounding gneisses. Layering is locally disrupted and rotated to varying degrees along discrete shear belts, which serve as avenues for the younger granitoid network. Metasedimentary rocks comprise rusty biotite-muscovite gneisses containing quartz-feldspar knots in the southernmost belts east of Reid Brook, and gray and pink magnetite-bearing quartzite, sillimanite-bearing psammite, and marble/calc-silicate rock in the northernmost belts on Akuliakatak Peninsula. White weathering metaleucogabbro and meta-anorthosite occur on Akuliakatak Peninsula and north of Voisey Bay. These form quite distinct units within the gneiss complex and, although strongly foliated and recrystallized, post-date all but the latest penetrative foliation in the gneisses. They contain rafts of the banded gneiss, rusty metasedimentary rocks and mafic gneisses. The fabric in the anorthositic rocks is simply a streaky discontinuous foliation defined by oriented hornblende (and orthopyroxene?); any layering present may reflect primary compositional variations, although no unequivocal primary structures were observed.

Metamorphic grade within rocks assigned to the Archean terrane varies from amphibolite to granulite facies. Observation of probable orthopyroxene cores in hornblende from some mafic units in the amphibolite facies areas, and similar cores in hornblende from metaleucogabbro on the Akuliakatak Peninsula, suggest that the whole complex is a variably retrogressed granulite terrane. Granulite facies rocks are best developed in a straight belt on the eastern tip of the island south of Akuliakatak Peninsula, where orthopyroxene is drawn out into parallelism with an intense, laminar, S>L fabric.

Churchill Province (Lower Proterozoic) gneisses. Metamorphic rocks assigned to the Lower Proterozoic form a distinct assemblage, characterized in the southernmost block by a mylonitic fabric. The northern part of the Churchill Province comprises rusty 'paragranulites' which have no counterparts in the south.

There are gneisses east and west of Makhavinekh Lake (Figure 2) that represent the direct southern continuation of the eastern margin of the Churchill Province in the Nachvak-Hebron area of northernmost Labrador (Wardle, 1983; Ryan *et al.*, 1983, 1984). They comprise a distinctive, white weathering, garnetiferous, quartzofeldspathic gneiss (Unit 2) with rusty paragneiss belts (Unit 4), and a foliated hypersthene tonalite (enderbite) to enderbitic gneiss (Unit 3). The white garnetiferous gneiss unit (equivalent to the Tasiuyak gneiss of Wardle, 1983) is 20 km wide at Makhavinekh Lake; it is absent in the northern and southern parts of the area, apparently having been removed by a series of sinistral strike-slip faults prior to intrusion of the younger plutons. As in northern exposures, it is here characterized by lilac to dark-red garnets (replaced by cordierite + hypersthene in the contact aureole of younger plutons), and an anastomosing quartz + feldspar foliation of mylonitic character. It is locally characterized by a sillimanite-biotite assemblage (sillimanite is replaced by spinel and cordierite in thermal aureoles) in which garnet forms augen. The linear fabric so characteristic of the unit in the Nachvak-Hebron area is generally absent here (presumably due to recrystallization) but can be detected in a few areas. The eastern part of the unit contains abundant screens and schlieren of rusty, graphitic, metasedimentary gneiss. Several discrete, graphitic, garnetiferous, sillimanite-biotite-sulfide paragneiss units (Unit 4, Plate 2), up to 0.4 km wide, are outlined in Figure 2. In the western part of the unit, there is a paucity of rusty schlieren and the rock is chiefly a garnetiferous quartzofeldspathic rock with no aluminosilicate phase identifiable in the field. The unit locally contains non-garnetiferous, white weathering, siliceous granitic layers (impure metaquartzite?), and garnetiferous, allanite-bearing, white pegmatites.

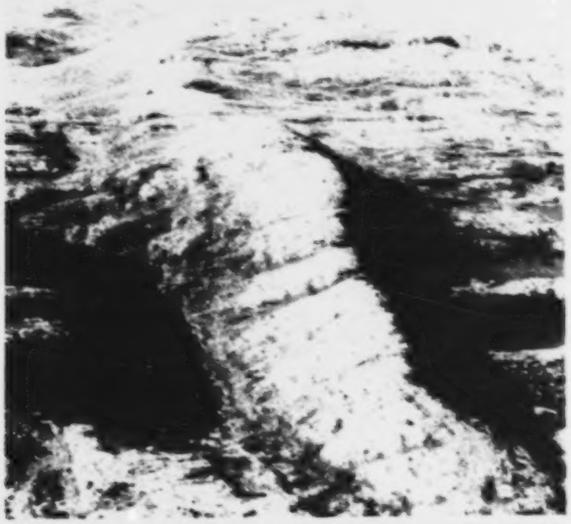

Plate 2: *Churchill Province gneisses. Spine of rusty, garnet-graphite paragneiss (Unit 4) rising above white garnet-quartz-feldspar gneiss (Unit 2), east of Makhavinekh Lake.*

Foliated enderbite (hypersthene tonalite) to enderbitic gneiss (Unit 3) forms several belts within the white, garnetiferous gneiss. These are characterized by fabrics that are defined by elongate, dark-brown orthopyroxenes and, to a lesser degree, a compositional banding.

An assemblage of gneissic rocks south of Konrad Brook appears for the most part, to be metamorphosed in the amphibolite facies and exhibits pervasive mylonitic foliations including localized ultramylonite zones. This assemblage is divided into several units (Figure 2) comprising, from west to east, a unit of mixed character, including pink granitic gneiss and augen gneiss (Unit 8), a white augen gneiss (Unit 7), and a gray biotite gneiss (Unit 5) containing rusty schlieren. Unit 5 is intruded by a white, siliceous, granitic gneiss (Unit 6).

The westernmost unit of mixed gneisses (Unit 8) is a variable package of rocks. It comprises well layered, migmatitic, gray gneiss and amphibolite, two varieties of granitic augen gneiss, and a pink granitic gneiss. The banded gneisses are gray, biotite-granodioritic gneisses and interbanded amphibolite, 4 m to 30 m wide, extensively injected by a white, granitic neosome that occurs as *lit-par-lit* masses and discordant vein networks. Within this migmatitic, gray gneiss/amphibolite association, there are isolated lenses of ultramafic rock and rusty garnetiferous biotite-rich gneiss of probable sedimentary parentage. The two varieties of augen gneiss are a gray, biotite-rich variety and a white, biotite-poor, garnetiferous variety, both derived from densely porphyritic granitic rocks. The gray unit is intrusive into the earlier banded-gneiss complex, and both are intruded by the white variety. The relationship of the pink granitic gneiss to the other members of this unit is unclear. This siliceous, pink weathering, mafic-poor granitoid is very homogeneous, and locally contains amphibolite inclusions.

A unit of white weathering, garnetiferous, granitic augen gneiss (Unit 7), probably representing a more extensive development of the white augen gneiss of the mixed unit, occupies a 5 km wide band south of the Kogaluk River (Figure 2). It locally contains numerous screens and schlieren of older, banded, biotite gneiss, rusty metasedimentary rock, and amphibolite. The fabric of this augen gneiss is an anastomosing, mylonitic type, culminating locally into narrow zones of ultramylonite.

Gray, migmatitic, biotite-rich gneiss containing rusty, sulfide-rich zones of probable metasedimentary origin, and minor amphibolite, constitute about one-third of the gneisses south of the Kogaluk River. This gneiss (Unit 5) is well layered, in places finely laminated, and commonly has white weathering granitic stringers parallel to the foliation. Garnet is locally replaced by cordierite + hypersthene. A white granitic gneiss (Unit 6) divides the biotite gneiss unit, and is a fairly homogeneous quartz-rich rock. It has discontinuous biotite foliae and scattered dark blebs, which appear to be biotite pseudomorphs of garnet.

Rusty weathering, granulite facies, cordierite-rich gneisses (Unit 9) form a distinctive unit along the northern fringe of the map area. These are different from the other Churchill Province gneisses, being rocks in which dark-blue, cordierite-bearing layers (2 to 10 cm wide) alternate with more massive hypersthene+quartz+feldspar layers. They also exhibit open folding and shallowly dipping layering. Berg and Wheeler (1976) reported the occurrence of the rare silicate osumilite from this unit, apparently a contact metamorphic mineral related to emplacement of the adjacent plutonic rocks.

Nain Igneous Suite

Anorogenic intrusive rocks of the study area are divided into three components, termed here the gabbroid plutons, the intermediate plutons, and the granitoid plutons.

Gabbroid plutons. The gabbroid plutons (Unit 10) encompass a wide variety of rocks which vary from olivine gabbronorites to anorthosite; gabbros are the most voluminous type. The gabbroids have three modes of occurrence in the map area, viz. as a core to an annular body of rapakivi granite north of Makhavinekh Lake, as part of a layered intrusion east of Reid Brook, and as inclusions of variable size in intermediate rocks south of the Kogulak River (Figure 2). Except for the layered intrusion, all the gabbroids seem to be correlative with the 'cumulate zone' as defined by Hill (1982) for plutons to the south. Textures vary from massive to diffusely layered, and from medium to very coarse grained (pegmatoidal), the latter grain size occurs especially in the anorthositic members. Labradorite schiller was noted in some of the anorthosites of this area, particularly in the northern pluton. Black olivine gabbro is widely developed east of Reid Brook, and forms a large inclusion in the granite east of Trout Pond. A similar dark-gray to black olivine gabbro, which occurs as part of the layered intrusion east of Reid Brook, is characterized by a radiating stellate growth of slender plagioclase crystals reminiscent of 'quench' textures (Plate 3). The other part of the intrusion is a well layered, orange-red weathering, troctolite and olivine norite (subunit 10a). The layered intrusion has a gently east-dipping (approximately 25°) contact against gneisses on its western margin, but is steeply dipping where the eastern contact was observed. The southern lobe has an antiformal shape; the olivine gabbro overlies the layered part. This intrusion may be younger than the other anorthositic rocks, and is probably equivalent to the Kiglapait intrusion and similar plutons in the area around and north of Nain.

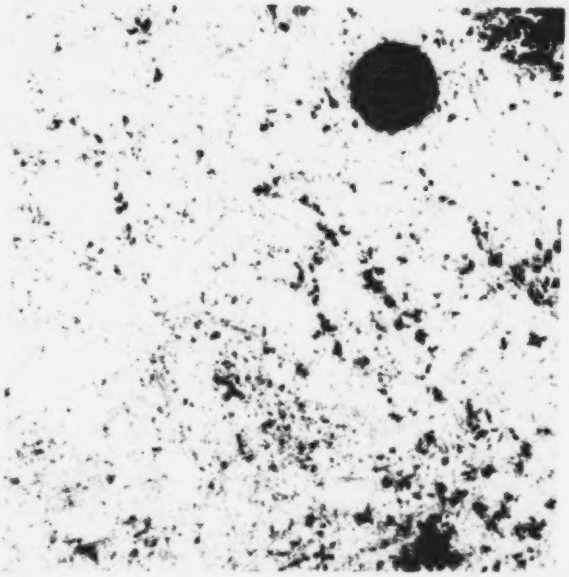

Plate 3: *Olivine gabbro. Stellate plagioclase growth in gabbro of layered intrusion (Unit 10) east of Reid Brook.*

Intermediate plutons. The intermediate plutons (Unit 11) comprise rocks which have a compositional range from hornblende-olivine-biotite gabbro to hornblende-clinopyroxene quartz monzonite. These rocks are best exposed and most widely developed in the region of Konrad Brook and the Kogaluk River; lesser amounts are present north of Trout Pond. They also temporally come between the gabbroid and the granitoid rocks (see below), but gradations with both the younger and older intrusions occur.

Rocks of intermediate composition are very conspicuous south of the Kogaluk River. They occur as chocolate-brown, crumbly weathering biotite gabbros and monzonites, which occupy a gently rolling plateau. Anorthosite inclusions stand out as rounded resistant knolls in contrast to the less resistant intermediate host rocks. Rare igneous layering indicates that the pluton forms an undulating, subhorizontal sheet, which consistently separates gabbroic anorthosite and Churchill Province gneisses. It is characterized by rafts of gabbroid, 1 m to 1 km long, in its interior portion (Plate 4). Texturally, the unit varies from massive subophitic with oikocrysts of clinopyroxene, to porphyritic with plagioclase and skeletal hornblende phenocrysts. Some of the 'porphyries' contain conspicuous dark-gray plagioclase 'phenocrysts'; these are in fact pseudoporphyries since the 'phenocrysts' are actually xenocrysts derived from fragmented anorthosite and leucogabbro, remnants of which are locally present in outcrop.

Plate 4: *Raft of anorthosite (Unit 10) in rusty gabbro (Unit 11), south of Konrad Brook.*

Several larger dikes emanate from the southern (lower) contact of the pluton into the gneisses (Figure 2). These dikes comprise an inner zone of medium to fine grained, quartz-bearing gabbro or diorite, and an outer zone of quartz-feldspar porphyry that exhibits an aphanitic chilled contact against the country rock. The dikes contain exotic inclusions of gabbroic anorthosite, and the adjacent gneiss.

The intermediate plutons north of Trout Pond have more restricted distribution than those to the south, and occur mostly as sheets within anorthosite. They do not exhibit to the same extent the crumbly weathering so characteristic of the southern exposures, and they also tend to be more porphyritic, in places containing 65 to 70 percent densely packed, subrounded, (alkali ?) feldspar phenocrysts in an opaque oxide, pyroxene (+ olivine?)-rich groundmass.

Granitoid plutons. The granitoid plutons (Unit 12) crop out in three separate areas: along the southern quarter of the study area, around Voisey Bay, and north of Makhavinekh Lake (Figure 2).

The southern belt of granitic rocks is the northward extension of a very large pluton outlined by Hill (1982), which extends a farther 50 km southward. The plutonic rocks of this area are predominantly medium grained, hypidiomorphic, fayalite-clinopyroxene-hornblende quartz monzonite and granite, including areas of quartz-feldspar porphyry and finer grained monzonite. The porphyry and fine grained monzonite appear to represent upper chilled phases that have been engulfed by the coarse grained granite.

Granitoid rocks around Voisey Bay are a similar, hypidiomorphic, pyroxene- and olivine-bearing quartz monzonite to granite. They are locally characterized by opalescent quartz, and are more biotite- and hornblende-rich than similar rocks to the south. Scattered ovoidal alkali-feldspar phenocrysts are present in some parts of this body.

The large elliptical pluton north of Makhavinekh Lake comprises predominently rapakivi granite containing ovoidal feldspar, granodiorite and quartz monzonite. Ovoidal alkali-feldspar phenocrysts, up to 5 cm in diameter, with zonally arranged mafic mineral inclusions and a plagioclase rim (Plate 5), occur throughout the pluton, but are more abundant in some areas than in others. Two phases can be identified in the field—a white to pink weathering phase resistant to weathering, and a brown crumbly phase that weathers very easily to a coarse grained grus in which the ovoidal feldspars remain as 'eggs'. Although not yet confirmed by petrography, the crumbly weathering rock appears to be an olivine-bearing phase. Locally, along the inner margins of the pluton where it forms a subhorizontal cap on anorthosite, there is a feldspar-rich phase in which abundant rounded feldspars are set in a dark, pyroxene-opaque oxide-rich groundmass. This densely porphyritic phase is mesoscopically identical to that associated with the intermediate sheets in this area.

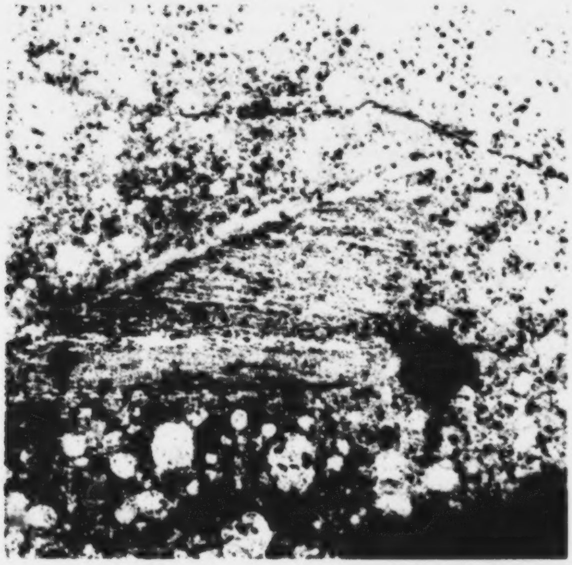

Plate 5: *Ovoidal feldspar in rapakivi granite (Unit 12) which contains gneiss inclusion, on north shore of Makhavinekh Lake.*

Contact Relationships of the Intrusive Rocks

An intrusive contact between the gabbroid plutons and Churchill Province gneisses south of Makhavinekh Lake has not been observed. In this area, the anorthositic and gabbroic rocks are separated from the surrounding gneisses by younger biotite gabbro and monzonite. The gabbroid pluton north of Trout Pond is separated from its Churchill Province country rock by rapakivi granite along most of its perimeter. However, in the north, there are several places where anorthositic gabbro is in close proximity to cordierite-rich granulite facies gneisses, and Wheeler (1974) indicates intrusive relationships between the two. Where observations have been made, there is a narrow fringe of brown gabbroic rock, like that in the intermediate plutons, separating the gneisses from the anorthositic pluton (see also Berg, 1980). These gabbros are characterized by fragments of anorthosite and variably digested cordierite-rich gneisses. Berg and Wheeler (1976) reported that these cordierite-rich granulites contain osumilite, a rather rare silicate which they concluded was generated by the contact effects resulting from the emplacement of the gabbroid pluton.

The layered intrusion east of Reid Brook has had no apparent effect on its Archean Nain Province country rock gneisses. Contacts are sharp and planar, and the olivine gabbro is chilled to a fine diabase adjacent to the gneisses.

The contact between the gabbro to monzonite pluton and the older rocks south of Makhavinekh Lake is exposed at several localities. Map pattern and topographic considerations (cf. Ryan and Lee, 1985) indicate that it is a subhorizontal sheet, the northern contact of which is the roof and the southern contact is the floor. The northern contact with the gneisses is usually sharp, with minor dike off-shoots. The pluton in this area varies from exhibiting little or no grain size reduction as the contact is approached to having a distinct chilled margin of diabase. The southern contact (floor) of the sheet, however, is characterized by a dark-gray quartz-feldspar porphyry, especially well developed in the western half of the body where large dikes of similar composition extend several kilometres from the sheet into the gneisses. Both the dikes and the main body have narrow, black, aphanitic, chilled rinds, which were partially peeled off and incorporated into the coarser grained gabbro-monzonite as magma intrusion progressed.

Observations from this area suggest that the intermediate sheet is the chief cause of contact metamorphism. It was noted that the white garnet-quartz-feldspar gneiss (Unit 2) displays well the contact effects, e.g., there is a progressive transformation of garnet to a cordierite + hypersthene symplectite, and of sillimanite to cordierite + spinel toward the sheet (Plate 6). Although the full extent of the contact aureole is not yet documented, field observations suggest that garnet is unstable at least 2 km away from the contact. This however may be an 'apparent thickness' due to the gently dipping nature of the sheet. As noted previously, the southern gabbro-monzonite pluton is intrusive into, and contains rafts of leucogabbro and anorthosite. Contact effects on these anorthositic rocks appear restricted to the transformation of original igneous pyroxene to a bright-green actinolitic amphibole.

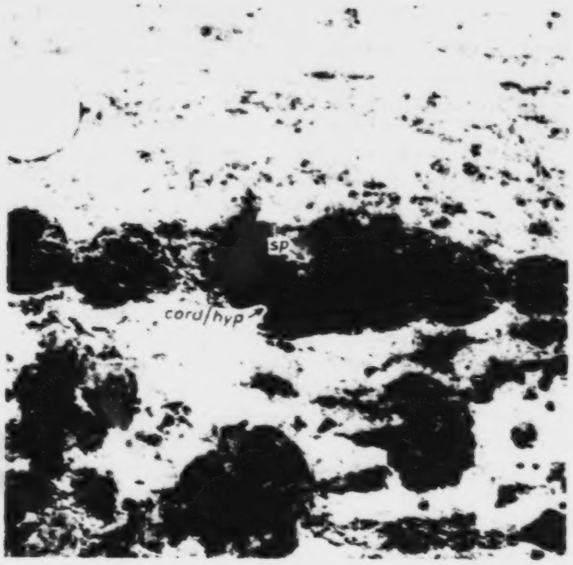

Plate 6: *Contact metamorphism of garnet-quartz-feldspar gneiss (Unit 2). Hypersthene + cordierite symplectic pseudomorphs of garnet, surrounded by darker spinel + cordierite pseudomorphs of sillimanite, south of Makhavinekh Lake.*

North of Trout Pond, the contact between the intermediate rocks and the Churchill Province gneisses is somewhat diffuse because the older rock is a rusty, schlieric, granoblastic, quartzofeldspathic granulite that superficially resembles the adjacent gabbros. The gneiss is cordierite bearing, and where digested by the gabbros, a cordierite restite is commonly preserved, giving rise to a cordierite-bearing igneous rock. Contact effects on the gneisses are not as easily defined here as they are to the south, but Berg and Wheeler (1976) and Berg (1980) document hypersthene+quartz+osumilite intergrowths in these gneisses adjacent to the gabbros, minerals which they attribute to thermal metamorphism.

The contact between the gabbro-monzonite (intermediate) plutons and the gabbroid rocks in the northern part of the map area exhibits somewhat ambiguous relationships. At their far northern exposures, the gabbros of the intermediate plutons are intrusive along the margins of the leucogabbroic and anorthositic rocks. However, some of the large dike-like bodies within the interior of the anorthosite pluton apparently have transitional contacts with gabbroic anorthosite over several metres and no discrete intrusive relationship can be demonstrated.

The granitoid plutons are the youngest major intrusive rocks in the area. They show few contact effects with the older rocks; the contact zone is usually an angular agmatite of older rocks pervaded by granite dikes. In several such zones, e.g., between rapakivi granite and gabbro in the north, and between rapakivi granite and black olivine gabbro east of Trout Pond, the dikes of granite are coarse grained and lack chilled margins, suggesting that the ambient temperature of the older rocks was similar to that of the granitoid magma at time of intrusion. It was observed, however, that 'bleached' zones occur in anorthosite in which plagioclase appears to be sericitized and the pyroxene is altered to amphibole adjacent to the rapakivi granite. Also, preliminary petrography suggests that the hypersthene+cordierite symplectites of the white garnet-quartz-feldspar gneiss are recrystallized to a biotite-garnet assemblage in the contact aureole of the granite in the southern part of the area.

The topographic distribution of the rapakivi granite-anorthosite contact north of Trout Pond (cf. Ryan and Lee, 1985), and observations of a gently dipping interface between the two, indicate that the granite forms a subhorizontal cap on the gabbroid pluton. The outer contact of the granite pluton was directly observed only west of Makhavinekh Lake, where the granite dips approximately 30° southward beneath the gneisses. Elsewhere there is a steep escarpment separating rapakivi granite on the highland from gneisses in the lowlands. A generally steeply dipping margin is suggested by the gently curved outline of the granite's outer contact, which contrasts sharply with the more irregular inner contact.

The contact between the intermediate plutons and the granites is usually an intrusive one. However, in some places in the north it appears gradational, exemplified by an increase in quartz and ovoid feldspar in the gabbroic to monzonitic rocks, which pass into rapakivi granite. This relationship is best displayed by some of the larger rapakivi granite dikes, which locally have border zones of either monzonite or hornblende gabbro.

In summary then, the field relationships between plutonic rocks indicate that the gabbroid plutons are intruded by the intermediate plutons, and both are intruded by the granitoid plutons. However, locally, there seems to be a gradation from anorthositic gabbros into the monzogabbros of the intermediate plutons, and a gradation from the intermediate plutons into rapikivi granite. These relationships suggest that three different magma batches co-existed, but underwent ordered crystallization to produce a temporal sequence, from oldest to youngest, of gabbroid plutons, intermediate plutons, and granitoid plutons.

The most profound contact effects resulting from emplacement of these magmas seems to be related to the intermediate plutons south of Makhavinekh Lake, marginal to which there is widespread transformation of country-rock mineralogy. Along the northern fringe of the area, however, it appears that the earlier gabbroid plutons were responsible for the contact metamorphism of a cordierite-rich gneiss unit.

MINERALIZATION

Gneissic rocks of the study area are locally characterized by rusty, sulfide-rich, lenses and discrete paragneiss belts several kilometers in length. These commonly contain 5 to 15 percent disseminated graphite and pyrite. Locally the gneisses contain discordant pegmatites and granite sheets of unknown affinity, which register up to 1300 cps on a GIS-4 scintillometer.

Anorthosite north of Trout Pond locally contains chatoyant plagioclase. The amounts noted to date are restricted to small (10 to 15 m^2) areas, and comprise randomly distributed crystals or crystal clusters in medium grained anorthosite or anorthositic gabbro. The color of individual crystals is a green or blue-green, including a zonation to a bronze variety. A black olivine gabbro dike in gneisses just east of Reid Brook displays a deeply weathered, orange-brown, sulfide gossan, a feature peculiar to this one area.

Granitic rocks lack any visible mineralization of economic interest, and show no anomalous radioactivity in regional scintillometer surveys. The only economically interesting mineral occurrence in these plutons is within a monzonite inclusion in rapakivi granite north of Reid Brook Pond. The inclusion contains globular concentrations of graphite up to 5 cm in diameter. This unusual feature seems to be a result of digestion of graphitic paragneiss by the monzonitic magma at depth, and the concentration of the graphitic restite into globlules before crystallization of the host.

SUMMARY

Field work during 1985 in the eastern part of the Nain-Strange Lake project corridor has outlined the distribution of gneisses of the Nain and Churchill provinces, defined the probable contact between the Nain and Churchill provinces, and subdivided the plutonic rocks of the Nain Igneous Suite into three regional-scale units. It has been demonstrated that a gabbro to monzonite pluton south of Makhavinekh Lake intrudes the earlier gneisses and anorthositic rocks as a subhorizontal sheet, and that rapakivi granite north of the lake forms a flat cap on a partially unroofed gabbroic pluton. Most of the contact metamorphic effects seen in the gneisses is attributed to emplacement of the intermediate plutons. Contact relationships indicate a temporal sequence of crystallization from gabbroic/anorthositic rocks to monzonitic/gabbroic rocks, and finally to granitic rocks. These relationships also suggest that all three magma associations may have co-existed at some point during their emplacement history. None of the granites are peralkaline, and potential for Strange Lake-type mineralization appears limited. The chief mineral of economic interest in the study area is labradorite, but the quantities outlined to date are not significant.

ACKNOWLEDGEMENTS

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PLUTONIC ROCKS OF THE EASTERN CENTRAL MINERAL BELT, LABRADOR: GENERAL GEOLOGY AND DESCRIPTION OF REGIONAL GRANITOID UNITS

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ABSTRACT

This preliminary report outlines results from a three-year project initiated in late 1984 to assess the potential of granitoid rocks in the eastern Central Mineral Belt for granophile mineralization, and gather information on the major early to middle Proterozoic batholiths of which they form a part.

Granitoid rocks in the area fall into two major groups. An earlier group (Makkovikian granitoids) consists of foliated to gneissic rocks emplaced c.1.85 Ga, contemporaneous with a major period of deformation and metamorphism. These contrast with a younger group of posttectonic intrusions that form the c.1.65 Ga Trans-Labrador batholith, which is generally undeformed or only weakly foliated over much of the study area. Although it includes layered gabbros, monzonites and syenites, the Trans-Labrador batholith is dominated mostly by granites and alkali-feldspar granites. The northern margin of the batholith in this area includes a number of small, leucocratic granite bodies whose outcrop patterns suggest that their upper surfaces are cut by the present erosion surface. Some of these bodies host Mo-Cu mineralization, and others appear to be spatially associated with hydrothermal veins containing Mo and base metal sulfides.

INTRODUCTION

Project Description

This project was initiated in late 1984 following previous recognition of the potential of some granites in the area for granophile mineralization (Ryan, 1977; Gower *et al.*, 1982; Wardle, 1984). The primary objective of this project is to assess the overall potential of granitoid rocks throughout the eastern Central Mineral Belt for granophile mineralization and to define areas underlain by highly evolved or specialized granites which may merit more detailed investigation or exploration in future years. A parallel objective is to develop an understanding of the anatomy, evolution and petrogenesis of the extensive 1.65 Ga granitoid terrane known as the Trans-Labrador batholith, which is one of the most important geological elements of central Labrador (Figure 1).

In view of the large areas underlain by granitoid rocks in the eastern Central Mineral Belt, it was decided that the initial phase of this project should involve an examination of regional lithogeochemical patterns, and the first field season was thus largely devoted to the completion of an extensive helicopter-supported rock sampling and mapping program. This work is aimed at delineation of broad petrographic subdivisions within the batholith and identification of areas of potential enrichment in lithophile elements of economic importance. It will also provide a systematic sample collection for subsequent geochemical and petrogenetic studies. This year's field work involved the collection of about 650 samples with an average site spacing of approximately 2 km, over a total area of approximately 5000 km², of which 60 to 70 percent is underlain by granitoid rocks. Additional detailed field work and sampling were carried out within several of the smaller granitoid plutons associated with known mineralization or considered to have potential for granophile deposits. Most of these areas will be revisited next year and examined in more detail.

Current research is directed at the examination of hand samples, stained slabs and available thin sections in order to outline a general framework of regional granitoid units, which will form a basis for assessment of geochemical data. Much of this framework is derived from previous subdivisions suggested by Gower *et al.* (1982) and Ryan (1985), with the addition of several new units defined by the initial results of this project.

Sampling and Mapping Methods

In view of the large size of the study area, a structured approach to mapping and sampling is required in order to cover all areas in more-or-less equal detail. The methods used in Labrador were derived mostly from those developed during the Ackley project (Dickson, 1983), which were in turn derived from a system devised by R.G.Garret in 1979. For a full discussion of the statistical basis for this and other sampling methods, the reader is referred to Garret (1983). The system utilizes a 2 by 2 km grid based on UTM co-ordinates, and sample locations are preselected on a random basis within each grid cell.

Random preselection of sample locations in this fashion has obvious advantages in any geochemical study involving statistical data analysis methods, but cannot readily be applied in the field, where outcrops are not randomly distributed. Nevertheless, the system worked very effectively in coastal areas and in areas of generally high elevations.

This project is a contribution to the Canada-Newfoundland Mineral Development Agreement, 1984-1989

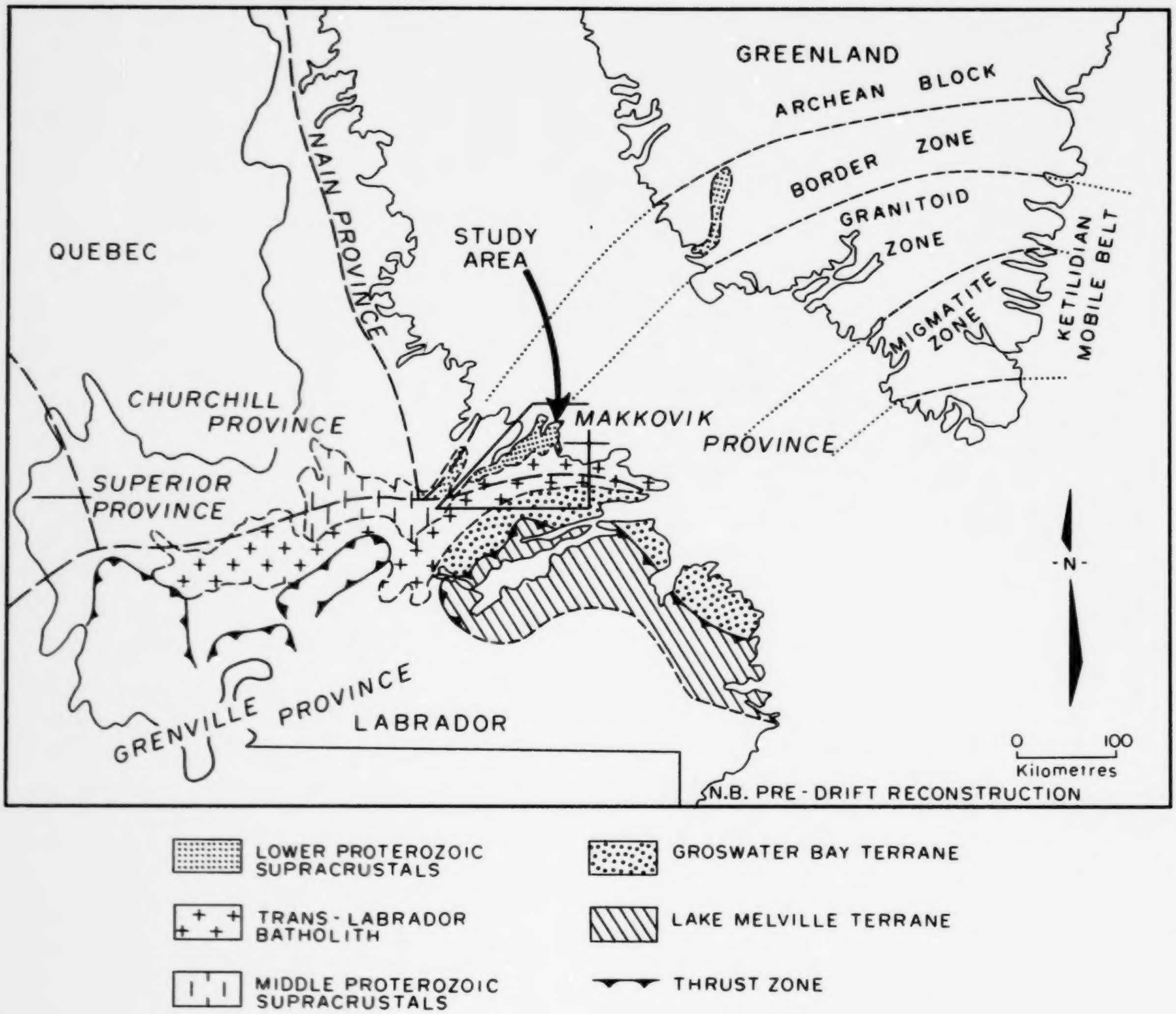
GREENLAND
ARCHEAN BLOCK
BORDER ZONE
GRANITOID ZONE
MIGMATITE ZONE
KETILIDIAN MOBILE BELT
QUEBEC
NAIN PROVINCE
STUDY AREA
CHURCHILL PROVINCE
MAKKOVIK PROVINCE
SUPERIOR PROVINCE
GRENVILLE PROVINCE
LABRADOR
-N-
0 100
Kilometres
N.B. PRE-DRIFT RECONSTRUCTION
LOWER PROTEROZOIC SUPRACRUSTALS
TRANS-LABRADOR BATHOLITH
MIDDLE PROTEROZOIC SUPRACRUSTALS
GROSWATER BAY TERRANE
LAKE MELVILLE TERRANE
THRUST ZONE

Figure 1: *Principal geotectonic elements of east-central Labrador, showing the extent of the Trans-Labrador batholith and adjacent terranes. The Groswater Bay terrane consists of quartzofeldspathic orthogneisses and paragneisses, and the Lake Melville terrane contains similar rock types with a higher proportion of paragneisses. Elements of the pre-Trans-Labrador batholith geology of the Makkovik Province appear to be correlative with the Ketilidian Mobile Belt of Greenland (after Gower and Ryan, in press).*

In poorly exposed areas, some difficulties were encountered and sample sites were dictated mostly by availability of outcrops and natural features for topographic control and landing spots. However, the original grid system was adhered to as much as possible to control sample spacing.

Location, Access and Topography

The field area forms a rough quadrilateral having a maximum length of about 130 km and a maximum width of about 75 km (Figure 1), including a deeply indented coastal strip, numerous offshore islands and adjacent inland areas . Access is provided by CN Marine coastal boat services and by scheduled air services from Goose Bay via LABAIR. The settlements of Makkovik and Postville provide good bases for field work in the eastern half of the area, and the BRINCO exploration camp at Melody Lake is ideally situated for work in the west. Helicopter and fixed wing support are available from Goose Bay, approximately 250 km to the southwest.

The topography of the area ranges from rugged barren mountainous terrain, containing 60 to 80 percent exposure along the coastal strip and south of Makkovik, to a sporadically exposed boulder-strewn plateau in inland areas to the south and west.

Previous Work

Thorough and detailed descriptions of previous work and mineral exploration throughout the area are given by Gower *et al.* (1982) and Ryan (1985), and only a very brief review is presented here.

The earliest work consisted largely of descriptions of coastal outcrops (Leiber, 1860; Packard, 1891; Daly, 1902), with some later mapping along the coast by officers of the Newfoundland Geological Survey and the Geological Survey of Canada (Kranck, 1939, 1953; Christie *et al.*, 1953; Douglas, 1953). 1:250,000 scale geological mapping was completed by the Geological Survey of Canada (Stevenson, 1970; Taylor, 1975).

In 1954 pitchblende was discovered near Makkovik, leading eventually to a 25-year period of uranium and lesser base-metal exploration by British Newfoundland Exploration Company Ltd (BRINCO) and several joint venture partners. Most of the exploration and research work from 1955 to 1978 was related to the search for economic mineralization in uranium-bearing supracrustal sequences. However, several more general studies were carried out via university theses, including regional geological and structural work by Clark (1970, 1973) and Marten (1977) in the Makkovik and Kaipokok Bay areas, and petrochemical studies of uranium-bearing volcanic rocks by White (1976) and Evans (1980).

The Newfoundland Department of Mines and Energy started work in the area in 1976 and regional 1:100,000 scale mapping was completed in 1980 (Bailey, 1978; Bailey *et al.*, 1979; Ryan and Harris, 1978; Doherty, 1980). Compilation and synthesis of this information was presented by Gower *et al.* (1982) for the eastern half, and by Bailey (1979) and Ryan (1985) for the west. Attention during these mapping programs was directed mostly toward supracrustal sequences and associated mineralization, but the areal importance of post-tectonic granitoid rocks was recognized, as was their polyphase and compositionally variable nature. However, many inland areas are very poorly known, and in some (particularly the large area south of the Adlavik Brook fault zone and around Big River) the granitoid rocks have not been subdivided.

Regional Geological Framework

The study area forms the eastern termination of the Central Mineral Belt of Labrador (Greene, 1974; Figure 1). The Central Mineral Belt is a zone of Aphebian and Helikian supracrustal sequences and associated intrusive rocks which contain a large number and variety of base-metal, uranium and rare-metal mineral occurrences. The belt lies along the junction between four structural provinces: the Nain (c.2.5 Ga), Makkovik (c.1.85 Ga) and Churchill (c.1.8 Ga) provinces to the north, and the Grenville Province (c.1.1 Ga) to the south (Figure 1). Most of the present study area lies within the Makkovik Province, but the southern edge and southwestern extremity are within the Grenville Province, where later tectonism obliterates primary features and relationships.

The largest geological element in the area is the Trans-Labrador batholith, a complex polyphase granitoid batholith that shows a range of ages (2.0 to 1.5 Ga) clustering mostly around 1.65 Ga. Mapping and geochronological studies in central Labrador (Wardle *et al.*, 1982; Thomas *et al.*, 1984; Nunn *et al.*, 1985) have shown that this feature can be traced to western Labrador, and Gower and Owen (1984) have suggested that it may also correlate with a similar 800 km long granitoid belt in southern Scandinavia. The Trans-Labrador batholith is bounded to the south by a number of thrust-bounded blocks containing high-grade gneisses, which may record the effects of broadly contemporaneous metamorphism. This middle Proterozoic orogenic event is now termed the Labradorian orogeny (Nunn *et al.*, 1985) and appears to represent an orogenic cycle separating the Hudsonian and Makkovikian (see below) events from the younger Grenvillian cycle.

GENERAL GEOLOGY

Introduction

The study area can be subdivided into four broad geological domains. These are as follows:

1. Archean basement rocks and reworked Archean basement exposed mostly to the north of Kaipokok Bay (Hopedale gneisses and Makkovik gneisses). These comprise banded quartzofeldspathic gneisses of probable igneous derivation with associated amphibolites and high-grade metasedimentary rocks. All of these rocks were remobilized to some extent during lower Proterozoic orogenic events, now termed the Makkovikian orogeny (Gower and Ryan, *in press*). In general, the degree of reworking increases from northwest to southeast toward Kaipokok Bay (Ryan and Kay,1982).
2. Lower Proterozoic supracrustal rocks (Aillik Group), consisting of two contrasting assemblages that do not necessarily represent a single stratigraphic sequence (Marten, 1977). The lower Aillik Group is exposed in a zone of intense folding and thrusting along Kaipokok Bay, and consists of mafic metavolcanic rocks and assorted arenaceous to pelitic metasedimentary rocks. The upper Aillik Group is more widespread, and consists of a thick pile of felsic volcanic and volcaniclastic rocks including related subvolcanic intrusives. In general, it appears less deformed than the lower Aillik Group, but this may to some extent be a function of differences in lithology.
3. Foliated to gneissic granitoid intrusive rocks containing north-northeast-trending fabrics; the granitoids intrude both the Archean basement and the Aillik Group. Marten (1977) established that this granitoid suite was emplaced syntectonically with respect to the main deformational events within the lower Aillik Group. These events correspond with the Makkovikian orogeny of Gower and Ryan (*in press*) and the term 'Makkovikian granitoids' is thus applied to intrusive rocks formed during this period. Limited radiometric age data suggest emplacement around 1.85 Ga.(Gandhi *et al.*, 1969; Brooks, 1982; 1983).

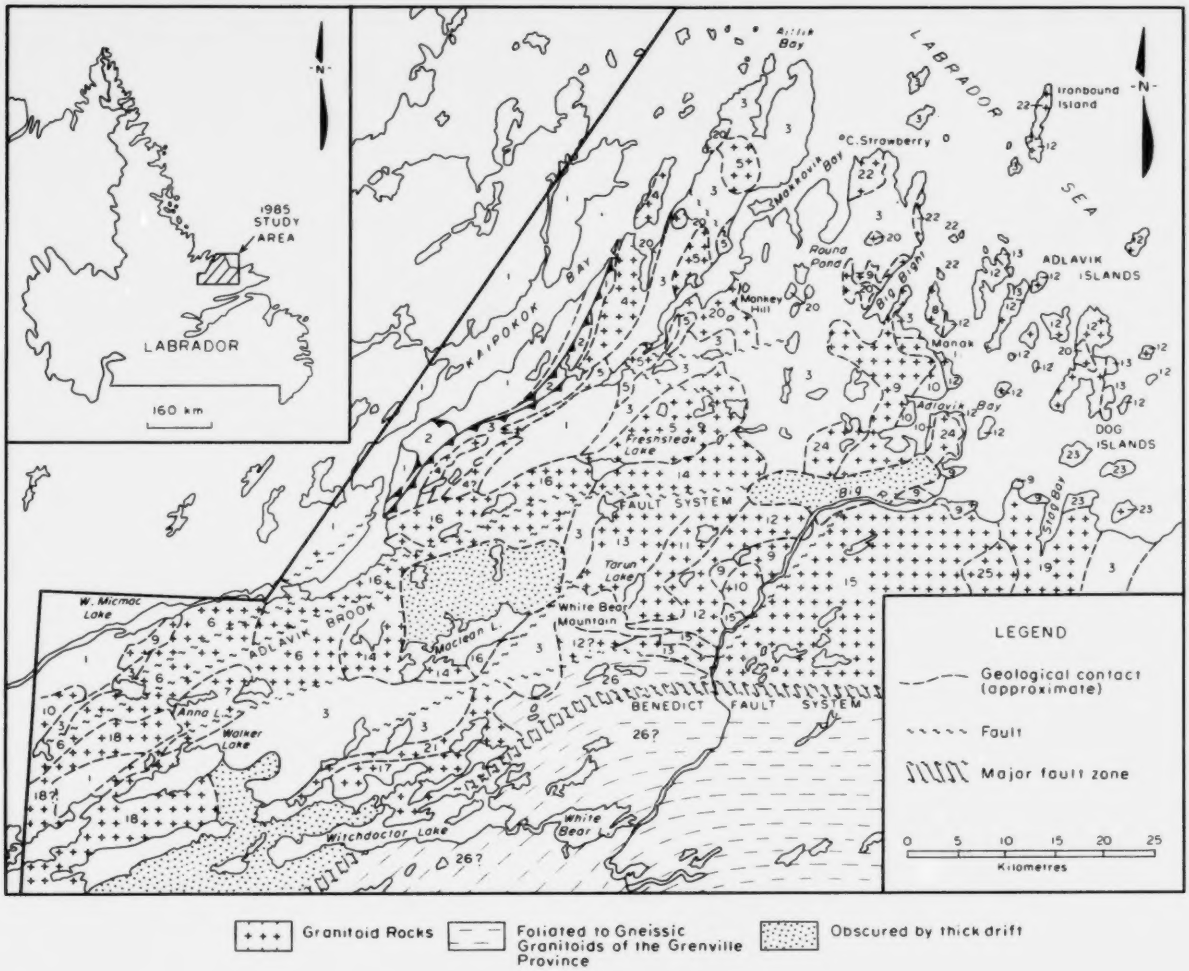
1985 STUDY AREA
LABRADOR
160 km
N
Ailik Bay
LABRADOR SEA
C. Strawberry
Ironbound Island
Makkovik Bay
KAIPOKOK BAY
Round Pond
Monkey Hill
Big Bight
ADLAVIK ISLANDS
Manak I.
Adlavik Bay
DOG ISLANDS
Freshsteak Lake
FAULT SYSTEM
Big R.
Strand Bay
Tarun Lake
White Bear Mountain
Maclean L.
ADLAVIK BROOK
W. Micmac Lake
Anna L.
Walker Lake
Witchdoctor Lake
White Bear L.
BENEDICT FAULT SYSTEM
LEGEND
Geological contact (approximate)
Fault
Major fault zone
0 5 10 15 20 25
Kilometres
Granitoid Rocks
Foliated to Gneissic Granitoids of the Grenville Province
Obscured by thick drift

Figure 2: *Generalized geological map showing the distribution of granitoid units within the Makkovikian and Trans-Labrador batholiths. Partly after Gower et al. (1982) and Ryan (1985), with revisions in some areas.*

4. Massive, dominantly posttectonic, polyphase granitoid intrusive rocks (Trans-Labrador batholith) emplaced c.1.65 Ga. These rocks are generally undeformed to only weakly foliated, except in the extreme south where they acquire strong east-trending fabrics of Grenvillian age. The Trans-Labrador batholith is dominated by quartz monzonite to granite, but includes a wide variety of rock types ranging from hornblende peridotites to alkali-feldspar granites. The batholith in this area is divided into three major intrusive suites by Gower *et al.*(1982) and Ryan (1985), but these do not necessarily represent single plutons or magma sequences.

The prominent structural feature of the area is a north-northeast-trending, strongly deformed, fold-thrust belt along Kaipokok Bay, whose trend is also shared by penetrative fabrics in Makkovikian granitoids. This belt is cross-cut by a system of east-trending faults and shear zones that mark the Grenville Front Zone. The most prominent of these are the Adlavik Brook fault system and the Benedict fault system, which divide the area into three blocks that exhibit differing amounts of Grenvillian deformation. North of the Adlavik Brook fault system, intrusive rocks of the Trans-Labrador batholith are generally undeformed, whereas the area between the two fault systems shows a heterogeneous development of strongly foliated and cataclastic zones with trends that are generally parallel to the major faults. South of the Benedict fault system, strong east-trending fabrics are almost ubiquitous within the study area. Mapping by Gower (1981, 1984) south and east of the present study area suggests that strain is more heterogeneous away from the immediate vicinity of the Grenville Front Zone. Orthogneisses within the Grenville Province may be deformed equivalents of the Trans-Labrador batholith. The area south of the Benedict fault system probably represents a somewhat deeper level within the batholith.

LEGEND

EARLY TO MIDDLE PROTEROZOIC

Grenville Province gneisses

26 Strongly deformed granitoid rocks (probably equivalent to the Trans-Labrador batholith).

Trans-Labrador batholith c. 1650 Ma

Smaller granitoid bodies

25 Medium grained, equigranular, alkali-feldspar granite.

24 Assorted granite, alkali-feldspar granite and quartz syenite.

23 *Dog Islands granite:* fluorite-bearing biotite granite similar to Strawberry granite (included in Benedict Mountains intrusive suite by Gower, 1981).

22 *Strawberry granite:* variably textured, porphyritic, biotite granite containing accessory fluorite.

21 Fine grained quartz monzonite to granite.

20 *Monkey Hill granite:* gray to pink, fine grained adamellite.

Benedict Mountains / Nipishish Lake intrusive suites

19 K-feldspar porphyritic granodiorite.

18 *Otter Lake-Walker Lake granite:* gray to pink, K-feldspar porphyritic, biotite-hornblende quartz monzonite to granite.

17 Pink equigranular alkali-feldspar leucogranite.

16 Pink to white biotite-hornblende granite and leucogranite.

15 Pink K-feldspar porphyritic granite to alkali-feldspar granite displaying 'pseudo-rapakivi' texture.

14 Gray to brown porphyritic granodiorite to adamellite.

Adlavik intrusive suite

13 Brown to gray K-feldspar porphyritic syenite.

12 Pink to white quartz monzonite.

11 Plagioclase porphyritic monzonite.

10 Diorite and monzodiorite.

9 Gabbro and leucogabbro.

EARLY PROTEROZOIC

Makkovikian granitoid rocks c. 1850 Ma

8 Gray leucocratic granodiorite.

7 Foliated granodiorite, diorite and quartz monzonite.

6 Pink, foliated, K-feldspar porphyritic granite and equigranular leucogranite.

5 Foliated biotite-hornblende quartz monzonite to granite, local fluorite-bearing leucogranite.

4 *Long Island quartz monzonite:* variably foliated melanocratic quartz monzonite.

Supracrustal rocks

3 **Upper Aillik Group:** felsic volcanic and volcaniclastic rocks, subvolcanic intrusive rocks, minor metasedimentary rocks and mafic volcanic rocks.

2 **Lower Aillik Group:** mafic metavolcanic rocks and assorted metasedimentary rocks.

ARCHEAN

1 Quartzofeldspathic orthogneisses, amphibolites, metasedimentary rocks and metamorphosed granitoid rocks (includes gneisses reactivated during early Proterozoic events).

The Adlavik Brook fault system appears to have a transcurrent component to its motion and a dextral displacement of about 20 km, based on the relative positions of supracrustal and granitoid units on either side of it (Gower *et al.*, 1982).

Figure 2 shows the generalized granitoid geology of the study area and is mostly intended to convey the general distribution of units; contacts are taken wherever possible from the more detailed ground-based mapping summarized by Gower *et al.* (1982). Some portions of Figure 3 differ from previous maps of the area, most particularly in areas south of the Adlavik Brook fault zone and around Big River, because very little information was previously available.

A total of 22 granitoid units have been distinguished within the study area, of which four are assigned to the earlier Makkovikian suite and 17 to the Trans-Labrador batholith (the status of one unit is unclear). Some of these units are equivalent to previously defined units or are extensions of such units, but several are new. The Archean gneisses and Aphebian supracrustal rocks (Units 1 to 3 on Figure 2) that form the country rocks to these granitoid units have not been examined in any detail and will not be discussed here. For full descriptions, see Gower *et al.* (1982) and Ryan (1985). Granitoid nomenclature follows the IUGS system proposed by Streckeisen (1976), but the term 'adamellite' has been retained for quartz-rich granitoids containing similar amounts of K-feldspar and plagioclase.

Makkovikian Granitoid Rocks (Units 4-7)

Foliated to gneissic granitoids of the Makkovikian batholith underlie much of the northwestern edge of the study area. They are characterized by the presence of strong penetrative fabrics that are locally cataclastic and have north to northeast trends. The granitoids are only rarely massive, even in their innermost portions. In the extreme southwest, where Grenvillian effects are significant, distinction between Makkovikian granitoids and deformed members of the Trans-Labrador batholith suite becomes locally difficult. However, there is still a distinct *regional* contrast in deformation state; for example, the granites of Unit 6 invariably display a strong fabric, whereas the adjacent Otter Lake-Walker Lake granite and Unit 16 of the Trans-Labrador batholith show only localized fabric development and are most commonly massive. A number of radiometric age dates obtained from Makkovikian granitoid rocks (Gandhi *et al.*, 1969; Brooks, 1979, 1982) suggest emplacement in the interval 1.95-1.80 Ga. Most Rb/Sr data and K/Ar data cluster around 1.85 Ga.

Long Island quartz monzonite (Unit 4). This unit is identical to that described by Gower *et al.* (1982) under this name, and previously was referred to as the Long Island gneiss by Gandhi *et al.* (1969). The main body of this unit is exposed on Long Island and extends southward onto the mainland for 10 to 15 km. Two smaller narrow belts of foliated granitoid along strike from the main body appear to be lithologically similar (on the basis of a few samples) and are here grouped with the Long Island pluton following Gower *et al.* (1982).

The Long Island suite is generally uniform in composition and is dominated by fine to medium grained, melanocratic, foliated quartz monzonites, which locally contain deformed enclaves of amphibolite and diorite. Only rarely is it gneissose, although local areas around the margins of the body have a banded appearance, which probably resulted from intense deformation of an enclave-rich phase. The most conspicuous textural feature is variably preserved zoned plagioclase phenocrysts. The unit typically contains 10 to 20 percent mafics by volume, with subequal amounts of biotite and hornblende (both appear to be primary) and some secondary biotite after hornblende.

Unit 5. This is a new unit which combines the Kennedy's Cove gneiss of Clark (1970) with other very similar foliated granitoid units described by Gower *et al.* (1982), and also includes an extensive body of foliated granite mapped during this project.

The unit includes three elliptical areas east of Makkovik and a large inland area south of Monkey Hill. It is a very distinctive, variably foliated, biotite or biotite-hornblende granite to leucogranite, commonly displaying a K-feldspar porphyritic texture, and, where more strongly deformed, an augen texture. Biotite is the dominant mafic phase in most samples, although a few samples from the Narrows area of Makkovik Bay contain only hornblende and are of quartz-monzonitic composition. Foliations are defined by streaky biotite aggregates and K-feldspar augen. A particularly distinctive variant of this granite is a buff-colored, equigranular, fluorite-bearing leucogranite, which has been recognized in all of the plutons described above. It is not clear if this is a separate phase of the granite or simply a textural variant of the dominant porphyritic granites, which also locally contain accessory fluorite. In general, the unit is rich in accessory phases such as apatite, allanite, sphene and zircon, and locally contains up to 1 percent sphene.

Unit 6. This unit underlies a large area in the southwest part of the study area. It was previously described by Bailey (1979) as pink leucogranite (Melody Hill granite). Unit 6, as defined here, includes two units described by Ryan (1985); a foliated granodiorite and a less abundant leucogranite. Samples collected this year demonstrate that there are at least two textural variants within this broad area, but also suggest a general similarity in composition and the possibility of a gradational relationship between them. The area is thus depicted as a single unit, although it may be possible to subdivide it on the basis of geochemical data. The unit as a whole displays a ubiquitous northeast- to north-northeast-trending foliation and is locally very strongly deformed, contrasting markedly with the younger Trans-Labrador batholith units that surround it. For this reason, it is assigned to the Makkovikian granitoids, and presumed to be about 1.85 Ga in age.

The most common rock types are gray to grayish-pink, coarse grained, K-feldspar porphyritic granite and a pink to red, coarse grained, equigranular biotite leucogranite, both of which have moderate to strong penetrative foliations. The generally similar composition and deformation state suggest that they are best grouped together at this stage in the project.

Other Foliated Granitoids (Units 7 and 8)

Unit 7. This unit comprises foliated granodiorite, diorite and quartz monzonite that were mapped by Bailey (1979) and

Ryan (1985) around Anna Lake. Samples collected this year suggest that these rocks represent a different unit than the adjacent Unit 6, but also demonstrate considerable variation in their characteristics. Rather than add three more units based on very small numbers of samples, these areas have been grouped together pending further information.

Unit 8. Foliated granite of Unit 8 occurs on Manak Island, just north of Adlavik Bay. It consists of medium to coarse grained, gray, leucocratic biotite granodiorite and granite, which display a moderate north-trending foliation but lack the intensity of deformation normally associated with the Makkovikian granitoids. The status of this unit is uncertain at present.

In addition to the regional units discussed above, two smaller foliated granitoid bodies occur near Kaipokok Bay that cannot satisfactorily be represented in Figure 2. These include the Brumwater granite (Marten, 1977), which is a leucocratic biotite granite that intrudes remobilized Archean gneisses, and the Pitre Lake granite, which is a narrow body of biotite-muscovite granite that intrudes lower Aillik Group metasedimentsary rocks. These granitoids have not yet been examined in detail in this study.

Trans-Labrador Batholith

Gower (1981) and Gower *et al.* (1982) divided the granitoid rocks now referred to as the Trans-Labrador batholith into the Adlavik Intrusive Suite, composed of gabbro and monzodiorite, and the Benedict Mountains Intrusive Suite, which is dominated by granitic rocks. Ryan (1985) defined a third division in central Labrador termed the Nipishish Lake Intrusive suite to encompass granitoid rocks that are somewhat younger than the other subdivisions. The following descriptions adhere to this general framework, although some units previously assigned to the Benedict Mountains Suite have been tentatively included with the Adlavik Suite. Radiometric age data for the eastern Trans-Labrador batholith suggests emplacement c.1.65 Ga, although the Nipishish Lake Suite may be as young as c.1.50 Ga. (Kontak, 1979; Brooks, 1982, 1983)

Adlavik Intrusive Suite (Units 9-13)

This suite was first named by Stevenson (1970), and has been described by Gandhi *et al.* (1969) and Clark (1973). Gower (1981) defined the Adlavik Intrusive Suite to include gabbros and diorites around Adlavik Bay, but in this report it is expanded to include monzonites, quartz monzonites and syenites that are all thought to be related. This revision is based mostly on the close spatial association between these rock types, originally pointed out by Gower (1981), and strengthened by the recognition during this project of the same package of rocks south of the Adlavik Brook fault zone. The main body of the suite is undated, but it is probably one of the older portions of the Trans-Labrador batholith as it is intruded by the Monkey Hill granite (Unit 20), which is dated at c.1.62 Ga.

Gabbro (Unit 9). The gabbroic unit of the Adlavik Intrusive Suite is present in two main areas between Big Bight and Adlavik Bay, and also underlies much of the Big River valley. The latter area is separated from the northern body by the Adlavik Brook fault zone, and thus may represent a different intrusion that was originally located farther to the east. The dominant rock type in both areas is a dark-gray to green, coarse grained gabbro to leucogabbro containing clinopyroxene, hornblende and biotite.The mafic minerals show a distinctive 'interstitial' texture to interlocking plagioclase laths, suggesting that the rocks originated as plagioclase cumulates with intercumulus mafic minerals. Most samples also contain minor interstitial K-feldspar. Some of the more mafic phases in marginal areas of the main body contain large pyroxene phenocrysts variably altered to amphibole, and may represent mafic mineral cumulates. Layering (including features typical of many layered intrusions) has been reported by Clark (1973, 1979), but is generally not obvious in inland outcrops.

Diorite-Monzodiorite (Unit 10). This facies of the suite is present around Adlavik Bay and in lesser amounts in the Big River valley. There does not appear to be a sharp contact between this unit and the gabbroic facies at Adlavik Bay, and the strong textural similarity between the two suggests that the relationship may be gradational. The diorite contains more K-feldspar than the gabbro and also small amounts of quartz. Locally, it displays a 'pegmatitic' or appinitic texture and contains large hornblende crystals up to 5 cm in length.

Plagiophyric Monzonite (Unit 11). This unit is present mostly in the area south of the Adlavik Brook fault zone, where it is positioned between Unit 12 monzonite and Unit 13 syenite. Two isolated samples from the Adlavik Islands are very similar, but do not allow a discrete unit to be defined in that area. It is a very distinctive rock containing 20 to 40 percent plagioclase phenocrysts, up to 2 cm across, that are set in a medium grained groundmass of K-feldspar, hornblende and minor quartz.

Monzonite-Quartz Monzonite (Unit 12). This unit corresponds to the Adlavik Islands monzonite of Gower (1981), which forms most of the inner Adlavik Islands. A belt of identical rocks extends from the Adlavik Brook fault zone toward White Bear Mountain in the centre of the area. The dominant rock type is a distinctive, fresh-looking, white to pale-pink, coarse grained monzonite containing euhedral hornblende and biotite. It is generally K-feldspar porphyritic and locally contains phenocrysts of both feldspars. It ranges in composition from monzonite to quartz monzonite and is locally potassic enough to qualify as a quartz syenite. Contacts between this unit and the gabbro-diorite (Units 9 and 10) around Adlavik Bay form an intrusive breccia zone that consists largely of gabbro blocks entrained in porphyritic quartz monzonite.

Syenite-Quartz Syenite (Unit 13). This unit combines syenites exposed on the outer Adlavik Islands with a unit previously designated as the Tarun syenite (Gandhi *et al.*, 1969) in the central part of the area. Although geographically discrete, rocks from these two areas are very similar and are in both cases associated with the other units of the suite. Unit 13 is dominated by gray-green to chocolate-brown, coarse grained syenites and quartz syenites containing perthitic

K-feldspar phenocrysts and interstitial altered clinopyroxene. Some areas are quartz rich and qualify as alkali-feldspar granites. A syenite dike typical of Unit 13 intrudes the agmatitic contact zone of Unit 12 quartz-monzonite, suggesting that this is the youngest unit within the Adlavik suite.

Benedict Mountains and Nipishish Lake Intrusive Suites (Units 14-26)

All other posttectonic intrusive rocks in the area are assigned to one or the other of these suites. As contact relationships are still largely unknown, the units that are the most important in terms of areal extent are discussed first. Five major regional units are recognized.

Unit 14. This is a new unit representing a subdivision of Unit 27 of Gower *et al.* (1982). It has been identified in two separate locations on either side of the Adlavik Brook fault zone; these are interpreted to represent portions of an originally continuous pluton. The dominant rock type is a gray to brown, medium grained, slightly porphyritic, hornblende-biotite granodiorite, quartz monzonite or adamellite. Small plagioclase phenocrysts are generally present and some variants contain phenocrysts of both feldspars. There is some similarity between these rocks and the plagiophyric monzonites of the Adlavik Intrusive Suite, but Unit 14 is generally more siliceous and finer grained.

Unit 15. This is a new unit representing a subdivision of the Benedict granite of Gower *et al.* (1982), and it occupies a large area southeast of Big River. The western margin of the unit is marked by a prominent escarpment along the south side of the Big River valley, which is interpreted as a fault zone. The most common rock type is a massive, pink, coarse grained, K-feldspar porphyritic granite to alkali-feldspar granite, which has a distinctive 'pseudo-rapakivi' texture, i.e., K-feldspar phenocrysts contain rounded plagioclase centres instead of being mantled by plagioclase. A non-porphyritic variant also occurs, but, to date, it has not been possible to delineate subunits within the map area. Both biotite and amphibole are present as mafic minerals and Gower (1981) reports the presence of riebeckite, suggesting that these rocks may have alkaline or peralkaline affinities. Petrographic studies will establish if this is a general feature of the unit.

Unit 15 lies close to the Benedict Fault zone and locally displays strong east-trending fabrics resulting from Grenvillian deformation. Augen gneisses south of the fault zone (Unit 26) may be highly deformed equivalents, as they have a similar K-feldspar-rich appearance.

Unit 16. This is a new unit representing a subdivision of Unit 27 of Gower *et al.* (1982). It forms an elongate mass along the north side of the Adlavik Brook fault zone, extending from Freshsteak Lake to the head of Kaipokok Bay, and it is massive and undeformed, contrasting strongly with the deformed granitoids of Unit 6, which abut Unit 16 in the southwest. The dominant rock type is a pink to white, biotite or biotite-hornblende leucogranite showing a variably porphyritic texture and euhedral mafic minerals. There is some grain size and textural variation within it, but in general the unit is very homogeneous. The general characteristics of this unit are reminiscent of the Strawberry and Dog Islands granites farther to the east, but some of the most porphyritic variants resemble some samples of the Otter Lake-Walker Lake granite (see below). Dextral movements inferred for the Adlavik Brook fault zone suggest that the continuation of this unit (if displaced) lies within the area underlain by Unit 6 and units of the Nipishish Lake Intrusive suite, but it has not been identified in this area. A small area south of Maclean Lake for which only two samples are available is tentatively grouped with this unit.

Unit 17. This unit corresponds generally with the 'Walker Lake granite' mapped by BRINCO geologists and described by Bailey (1979) and Gower *et al.* (1982). The term 'Walker Lake' is already in use as a rock name elsewhere and Gower, *et al.* (1982) recommended that its use be discontinued. Granites of Unit 17 are exposed mostly on the north side of Witchdoctor Lake, and are dominated by white to pink, coarse grained, equigranular alkali-feldspar granite containing minor biotite. It is close to the fault zones marking the northern margin of the Grenville Front Zone, and is locally foliated. The southern limit of the unit is unknown due to heavy drift cover.

Otter Lake - Walker Lake Granite (Unit 18). The Otter Lake-Walker Lake granite is one of two major subdivisions of the Nipishish Lake intrusive suite defined by Ryan (1985). The Nipishish Lake suite was originally separated from the Benedict Mountains Intrusive suite of Gower *et al.* (1982) because parts of it intrude the Paleohelikian supracrustal rocks of the Bruce River Group, suggesting that it may be younger than most of the other granitoids, which are nonconformably overlain by the Bruce River Group. However, these relationships do not rule out the possibility that portions of the Benedict Mountains suite are time-equivalents of the Nipishish Lake suite, and an unpublished U-Pb age on the Bruce River Group (T. Krogh, personal communication to R.J. Wardle, 1985) suggests that it may in fact be about 1.65 Ga old and coeval with much of the Trans-Labrador batholith.

Within the study area, Unit 18 is dominated by massive, medium to coarse grained, gray to pink, K-feldspar porphyritic granodiorite to granite and quartz monzonite containing biotite and/or hornblende. The texture is locally either seriate or equigranular. Blue quartz is particularly characteristic, as is a greenish hue caused by saussuritization of plagioclase. In addition to those areas indicated by Ryan (1985), an area northwest of Walker Lake is underlain by similar, but somewhat more texturally variable granitoids. This has been tentatively included with the Otter Lake-Walker Lake granite, but may represent a separate subunit.

Unit 19. A few samples were collected this summer from a megacrystic granodiorite unit defined by Gower (1981) around Stag Bay. This unit does not appear to fit readily with any of those described above and it is thus shown as a discrete unit in the extreme southeast part of the study area. Gower (1981) mapped similar rocks farther to the east in the Benedict Mountains, suggesting that this may be an important component of the Trans-Labrador batholith elsewhere.

Smaller Granitoid Plutons and Plugs (Units 20-25)

In addition to the regional granitoid units discussed in the preceding section, numerous smaller bodies of granite and leucogranite are present throughout the area, particularly in the north, where a higher level within the batholith appears to be exposed. These have been grouped into seven units, most of which correspond with units defined by Gower (1981) and Gower *et al.* (1982).

Monkey Hill granite and related rocks (Unit 20). This unit is largely equivalent to Unit 28 of Gower *et al.* (1982), but includes some additional areas recognized during this project. The unit is composite, as it includes most of the fine grained granites in the area. The type locality is a small pluton exposed south of Makkovik Bay, which consists mostly of a quartz-rich, fine to medium grained, pink to pinkish-gray adamellite or granite. Most samples contain equal amounts of the two feldspars, which gives the rock a distinctive 'speckled' appearance when stained. The normal mafic mineral is biotite, which is extensively to completely altered to chlorite. The main body displays little textural or grain size variation and is very homogeneous.

Of more interest from an economic point of view are a number of satellite intrusions within 10 to 15 km of the main body, some of which either host mineralization or are spatially related to it. The granite at Duck Island in Kaipokok Bay appears to be a small plug or cupola of altered leucogranite containing disseminated pyrite and molybdenite, with lesser chalcopyrite and bornite. Rather similar pyritized granite plugs in the Round Pond area are spatially associated with hydrothermal veins carrying molybdenite, pyrite and chalcopyrite. Details of this mineralization are discussed by Wilton *et al. (in preparation)*.

Several other small bodies of fine grained granite with broadly similar characteristics are grouped with the Monkey Hill granite suite, but these are not presently known to host any mineralization.

Unit 21. This unit corresponds to a unit previously defined by Bailey (1979) south of Maclean Lake, which he considered to be comagmatic with Aillik Group rhyolites. It is a fine grained, equigranular, leucocratic quartz monzonite to granite, which is locally difficult to distinguish from recrystallized members of the Aillik Group. However, L. McKenzie (personal communication, 1985) has identified clear intrusive contacts, suggesting that it is a younger post-tectonic body. Unit 21 contains a molybdenite showing near Burnt Lake, which locally contains high-grade mineralization and is hosted by granite similar to that observed at Duck Island.

Strawberry granite (Unit 22). This unit generally corresponds with Unit 29 of Gower *et al.* (1982), but does not include the granite of Manak Island, which is now tentatively interpreted to be part of the earlier Makkovikian suite. The main Strawberry granite pluton is a small, rounded body that intrudes Aillik Group volcanic rocks northeast of Makkovik. The dominant rock type is a coarse grained, pink to orange-red K-feldspar porphyritic biotite granite containing conspicuous accessory fluorite. As with the Monkey Hill granite, the biotite is strongly altered to chlorite. Much of the pluton is homogeneous, but a very distinctive biotite layering, displaying trough-like patterns highly reminiscent of cumulate layering, is present in several localities, and a large cumulate-layered block of gray granite was observed in one outcrop.

Despite the homogeneity of central parts of the body, the Strawberry granite displays considerable variation in both texture and grain size around its margins, where three or four phases can be recognized. These include fine grained granites containing disseminated fluorite, which may represent a chilled roof or border facies. Near its outer contacts, the granite contains numerous xenoliths of fine grained granite, some of which are cut by biotite-rich breccia zones, which may be indicative of volatile exsolution and hydrothermal activity. The southern contact zone of the body is particularly variable and also contains pegmatite sheets, again suggestive of a fairly high volatile content. Pegmatites containing a hard, green mineral, thought to be beryl, were also observed in one coastal exposure.

The northern half of Ironbound Island is also tentatively grouped with Unit 22. Granites in this area are texturally variable, but are mineralogically similar to the Strawberry granite and locally contain disseminated fluorite.

Dog Islands granite (Unit 23). This unit is identical to that described by Gower (1981) and is a coarse grained biotite granite containing accessory fluorite, similar in many respects to the Strawberry granite, but generally equigranular rather than porphyritic. However, locally the granite appears to be slightly quartz porphyritic. The most obvious contrast with the Strawberry granite is an overall textural homogeneity, and a conspicuous lack of fine grained phases and pegmatites. Biotite layering with a cumulate-like appearance is present in two localities. Quartz-feldspar and feldspar porphyry dikes that occur on the nearby Adlavik Islands may be related to this body.

Unit 24. This unit includes two small granite bodies in the Adlavik Bay-Big River area that do not readily fit into any of the groups discussed above. The unit includes rocks previously assigned to the Monkey Hill granite, and also to the Tarun syenite unit of Gower *et al.* (1982). They are typically medium to coarse grained, buff to gray, porphyritic alkali-feldspar granites, which locally grade into quartz syenites. Coarsely perthitic K-feldspar phenocrysts are a characteristic feature, but there are also equigranular variants and fine grained granites in this area. This map unit is not well defined, but the rocks included within it seem to have more affinity for one another than for any of the other units in the Trans-Labrador batholith.

Unit 25. This unit corresponds to a small area of coarse grained, equigranular, pink alkali-feldspar granite, which forms a prominent hill in the extreme southeast part of the area. It is clearly different from the adjacent Unit 15 granites, and may perhaps be part of a more extensive unit outside the study area, as Gower (personal communication, 1985) has collected similar rocks well to the south of here.

Grenville Province Gneisses (Unit 26)

Areas to the south of the Benedict fault system are underlain by strongly foliated to gneissic granitoid rocks which are presumed to be largely equivalent to granites of the Trans-Labrador batholith north of the fault zone. Unit 26 is dominated by pink to buff, augen-textured microcline-rich granitoids containing a variably developed cataclastic fabric. These rocks could perhaps be derived from the adjacent and compositionally similar Unit 15.

MINERAL POTENTIAL

In the absence of geochemical data from the 1985 field program, it is a little premature to attempt a detailed discussion of the granophile mineral potential of the area. However, some general comments are possible.

Sampling carried out in 1985 demonstrates that, even though the Makkovikian and Trans-Labrador batholith granitoids are compositionally varied, granites and alkali-feldspar granites are the dominant components of both groups. These siliceous, evolved rocks merit further examination should geochemical data suggest anomalous enrichment in granophile trace elements of economic interest. Of the new regional units defined in this report, Units 15, 16 and 17 appear to hold the most promise.

The Adlavik intrusive suite, which appears to be more areally extensive than previously thought, is dominated by quartz-poor granitoids that appear to be related components of a layered mafic-intermediate intrusion. Although the gabbroic to monzonitic facies of the suite is probably of limited potential for granophile mineralization, the syenites and quartz syenites may merit more detailed examination. If these are indeed the final differentiates of the Adlavik magma, it is possible that they may be enriched in a variety of economic elements. Analytical data for similar syenites on the Ragged Islands, just east of the study area, suggest higher than normal levels of REE and other lithophile elements (Gower, personal communication, 1985). An area of particular interest is the poorly known inland portion of this unit around Tarun Lake, which is close to Aillik Group country rocks (and thus perhaps exposed at high levels).

Makkovikian granitoids include extensive leucocratic granites in the form of Units 5 and 6. In the latter unit, high-grade uranium mineralization was discovered in altered and brecciated granitoid boulders several years ago by BRINCO geologists, but the source was not located. Some of the Unit 5 granites display signs of fluorine enrichment and should not be dismissed in any evaluation of the area.

The units with the greatest economic potential are a number of smaller granitoid bodies in the northern part of the area, which have some of the characteristics of epizonal granites traditionally regarded as favourable environments for granophile mineralization. Of these, the Monkey Hill granite and the granites of Unit 21 are the most obvious examples, as they host or are associated with Mo-Cu mineralization in several areas. The Strawberry granite has fine grained marginal phases and other features suggesting a high level of emplacement and the presence of volatiles during crystallization. It is also in close proximity to molybdenite showings around its southern margin.

The most favourable zones within small specialized granitoid bodies are typically within their roof zones, and mineralization is commonly concentrated in or around small plugs or cupolas on the upper surface of the pluton. Map patterns in the northern part of the Trans-Labrador batholith strongly suggest that the present erosion surface cuts the upper levels of several small granitoid bodies, and also that large areas underlain by the upper Aillik Group (Unit 3) may be underlain by granite at relatively shallow depths. This entire area is thus worthy of further investigation.

The Dog Islands granite is a fluorite-bearing leucogranite, similar in many respects to the Strawberry granite. However, the overall homogeneity and lack of pegmatites and aplites suggest that it may represent a deeper level, and there is no evidence of a preserved roof zone or border facies. Units 24 and 25 are as yet poorly known, but both are in close proximity to Aillik Group supracrustal rocks, suggesting that the erosion surface truncates the structural top of the plutons.

Future field work will be aimed at establishing contact relations between the regional subdivisions outlined in this report, and also examination of areas which appear to have economic potential on the basis of geochemical data. The regional geochemical survey coverage will be extended, and more detailed mapping is planned for some of the smaller plutons, and particularly the Monkey Hill and Strawberry granites.

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GEOLOGY OF THE SAND HILL RIVER - BATTEAU MAP REGION, GRENVILLE PROVINCE, EASTERN LABRADOR

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ABSTRACT

The Sand Hill River - Batteau map region is subdivided into six structural-lithological entities, namely the 1) Domino domain, 2) Earl Island domain, 3) Paradise metasedimentary gneiss belt, 4) Sand Hill Big Pond gabbronorite, 5) Paradise Arm pluton, and 6) the White Bear Arm complex. The Domino and Earl Island domains consist of granitoid plutonic rocks and orthogneiss, together with layered mafic intrusions and rare metasedimentary gneiss. The Paradise metasedimentary gneiss belt comprises cordierite-garnet-sillimanite-kyanite pelitic gneiss with minor quartzite, psammitic gneiss, calc-silicate rocks and amphibolite. Sapphirine and orthopyroxene are present in metasedimentary gneiss adjacent to the Sand Hill Big Pond gabbronorite. The Sand Hill Big Pond gabbronorite and White Bear Arm complex are both composed of anorthosite, norite, gabbro and monzonite, and are interpreted as having been contiguous prior to the emplacement of the linear Paradise Arm pluton. Other rocks mapped include pre-Grenvillian mafic dikes of various ages, and late Precambrian - early Paleozoic north-northeast- trending mafic dikes.

Regional structures have a consistent west-northwest trend and are associated with tight folds and major strike-slip faults. A north-directed thrust was mapped in the northeast part of the area. Many prominent photolineaments are interpreted to be related to post-Grenvillian faulting and dike emplacement.

The best prospects for economic mineralization are sulfide-rich zones and muscovite-rich pegmatite in the Paradise metasedimentary gneiss belt.

INTRODUCTION

Reconnaissance geological mapping at 1:100,000 scale of the Sand Hill River - Batteau map region in 1985 marks the second year of a 5-year Canada - Newfoundland joint project, aimed at completing mapping of an 80 km wide coastal fringe of the Grenville Province in southeastern Labrador.

The Sand Hill River - Batteau map region comprises seven NTS 1:50,000 scale map areas (3E/4,5,12 and 13H/1,2,7,8), which encompass an area of approximately 6100 km^2 (Figure 1). The only previously published geological map for the area is that of Eade (1962) at 1:50,000 scale. Apart from very small areas of metasedimentary and mafic gneiss, Eade showed three broad units: granitic gneiss, granitic plutons and gabbroic intrusions. In a general way, this project has confirmed his lithological subdivision, although at first sight the revised map (Figure 2) appears to bear little resemblance to that of Eade. Major revisions have been made to the positions of many geological boundaries and much of Eade's granitic gneiss unit has been identified as metasedimentary gneiss and extended well beyond its former boundaries.

Apart from mineral exploration activity, other geological investigations have been confined to coastal localities. These areas were initially visited by Lieber (1860), Packard (1891) and Daly (1902), and more recently by Christie (1951), Douglas (1953) and Kranck (1939, 1953). In addition, Grasty *et al.* 1969) reported K-Ar ages for a granitic intrusion and two mafic dikes from the northeast part of the region.

Reconnaissance mineral exploration activity, carried out by British Newfoundland Corporation (BRINCO) Ltd., has been confined mostly to the southwest portion of the map area. Initial investigations were by Piloski (1955), and later by Kranck (1966) and Bradley (1966). More detailed mapping was done by Donohue (1966) in the Sand Hill Big Pond area.

The present mapping has benefited from complete aeromagnetic map coverage (Geological Survey of Canada, 1974a,b) and extrapolation of units from previously mapped areas to the north and west (Gower *et al.*, 1982, 1983, 1985; Owen *et al.*, 1983).

This project is a contribution to the Canada-Newfoundland Mineral Development Agreement, 1984-1989

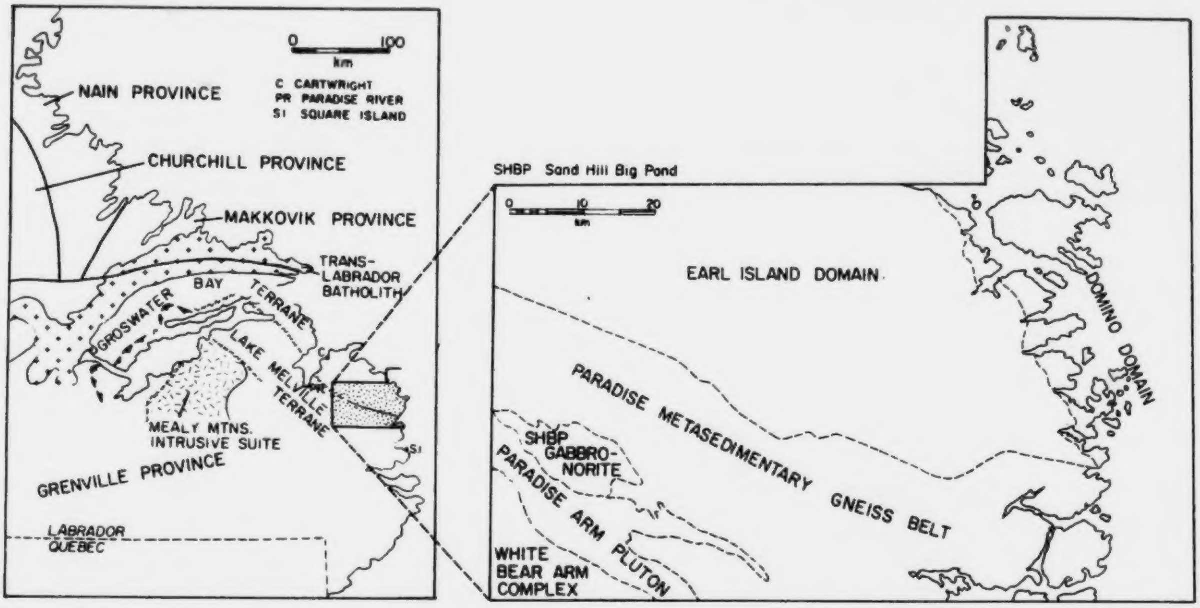
0 100
km
C CARTWRIGHT
PR PARADISE RIVER
SI SQUARE ISLAND
NAIN PROVINCE
CHURCHILL PROVINCE
MAKKOVIK PROVINCE
TRANS-LABRADOR BATHOLITH
GROSWATER BAY TERRANE
LAKE MELVILLE TERRANE
C
PR
SI
MEALY MTNS. INTRUSIVE SUITE
GRENVILLE PROVINCE
LABRADOR
QUEBEC
SHBP Sand Hill Big Pond
0 10 20
km
EARL ISLAND DOMAIN
DOMINO DOMAIN
PARADISE METASEDIMENTARY GNEISS BELT
SHBP GABBRO-NORITE
PARADISE ARM PLUTON
WHITE BEAR ARM COMPLEX

Figure 1: *Location and structural-lithological subdivision of the Sand Hill River - Batteau map region, Grenville Province, eastern Labrador.*

REGIONAL SETTING AND SUBDIVISION OF MAP AREA

The study area is situated entirely within the Grenville Province and straddles the southeastward extension of the boundary between the Groswater Bay and Lake Melville terranes (Gower, 1984; Gower and Owen, 1984). The location of the area is shown in Figure 1.

The map area can be divided into six major lithological entities. These are: 1) Domino domain, 2) Earl Island domain, 3) Paradise metasedimentary gneiss belt, 4) Sand Hill Big Pond gabbronorite, 5) Paradise Arm pluton, and 6) White Bear Arm complex. The Domino domain and Sand Hill Big Pond gabbronorite are new informal names; the other terms were introduced by Gower *et al.* (1985). From previous mapping and regional geological synthesis, it is anticipated that the Earl Island domain would intersect the coast roughly between Porcupine Bay and Comfort Bight, and that the area to the north would compare most closely with typical Groswater Bay terrane gneisses mapped farther northwest. Instead of the predicted pattern, it appears that the whole coastal region (Domino domain) differs, both in rock types present and their variability, from the interior (Earl Island domain). This variability could be simply an artifact of better coastal exposure, and lithological contrasts may be a result of preferential weathering and lack of exposure of selected units inland. Therefore, pending further work, the Domino and Earl Island domains are described separately as distinct lithological entities.

Domino Domain

The Domino domain, named after Domino (Figure 2), consists of granitoid plutonic rocks, layered mafic intrusive bodies and minor metasedimentary gneiss. Severely deformed and migmatized derivatives of the granitoid plutonic rocks are separately designated as orthogneiss in Figure 2. The Domino gneiss of Lieber (1860) was not classified, by our criteria, as a gneiss at its type locality, but instead was mapped as a fairly homogeneous, K-feldspar megacrystic, granitoid plutonic rock.

The granitoid plutonic rocks include biotite- and hornblende-bearing diorite, quartz diorite, monzonite, quartz monzonite, hornblende-biotite granodiorite, biotite granodiorite and muscovite-biotite granite. A notable feature of the Domino domain is the common occurrence of megacrystic variants of the granitoid rock types. The rocks are mostly medium grained, but include fine and coarse grained types. Color varies from black and white, or gray in the dioritic units to pink, creamy or brown in the granites. The mineralogy comprises a plagioclase-quartz-biotite ± K-feldspar ± epidote assemblage including accessory apatite, sphene, allanite, opaque minerals and, locally, garnet. In places, the rocks are homogeneous and weakly foliated, elsewhere they are stongly deformed and migmatized and grade into well banded orthogneiss.

The granitoid plutonic rocks are intruded by minor granitic intrusions of several ages and pre-Grenvillian mafic dikes of at least two ages. The earlier dikes are metamorphosed to amphibolite facies; they are strongly deformed and locally have a net-veined (agmatitic) appearance where injected by granitic leucosome. The later dikes, which truncate the more strongly deformed earlier mafic dikes (Plate 1), lack net-veined characteristics but also have a metamorphic (amphibolite-facies) mineralogy. Some mafic dikes contain plagioclase phenocrysts.

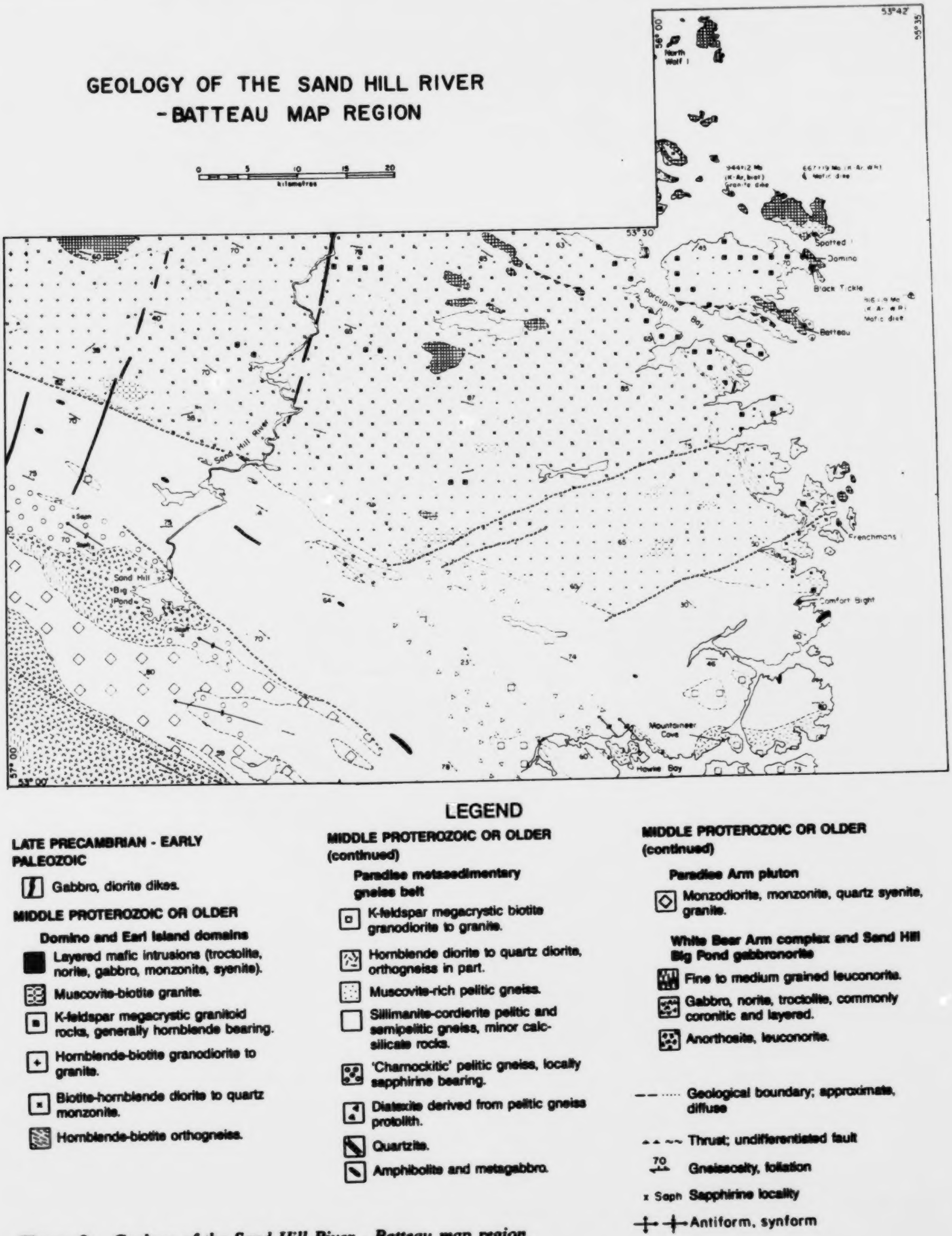
GEOLOGY OF THE SAND HILL RIVER
- BATTEAU MAP REGION
0
5
10
15
20
kilometres
53°42'
55°35'
56°00'
North Wolf I.
944±12 Ma
(K-Ar, biot)
Granite dike
667±19 Ma (K-Ar, WR)
& Mafic dike
53°30'
Spotted I.
Domino
Black Tickle
916±9 Ma
(K-Ar, WR)
Mafic dike
Porcupine Bay
Batteau
Sand Hill River
Saph
Sand Hill
Big
Pond
Frenchmans
Comfort Bight
Mountaineer Cove
Hawke Bay
57°00'
53°00'
LEGEND
LATE PRECAMBRIAN - EARLY PALEOZOIC
Gabbro, diorite dikes.
MIDDLE PROTEROZOIC OR OLDER
Domino and Earl Island domains
Layered mafic intrusions (troctolite, norite, gabbro, monzonite, syenite).
Muscovite-biotite granite.
K-feldspar megacrystic granitoid rocks, generally hornblende bearing.
Hornblende-biotite granodiorite to granite.
Biotite-hornblende diorite to quartz monzonite.
Hornblende-biotite orthogneiss.
MIDDLE PROTEROZOIC OR OLDER (continued)
Paradise metasedimentary gneiss belt
K-feldspar megacrystic biotite granodiorite to granite.
Hornblende diorite to quartz diorite, orthogneiss in part.
Muscovite-rich pelitic gneiss.
Sillimanite-cordierite pelitic and semipelitic gneiss, minor calc-silicate rocks.
'Charnockitic' pelitic gneiss, locally sapphirine bearing.
Diatexite derived from pelitic gneiss protolith.
Quartzite.
Amphibolite and metagabbro.
MIDDLE PROTEROZOIC OR OLDER (continued)
Paradise Arm pluton
Monzodiorite, monzonite, quartz syenite, granite.
White Bear Arm complex and Sand Hill Big Pond gabbronorite
Fine to medium grained leuconorite.
Gabbro, norite, troctolite, commonly coronitic and layered.
Anorthosite, leuconorite.
Geological boundary; approximate, diffuse
Thrust; undifferentiated fault
70 Gneissosity, foliation
x Saph Sapphirine locality
Antiform, synform

Figure 2: *Geology of the Sand Hill River - Batteau map region.*

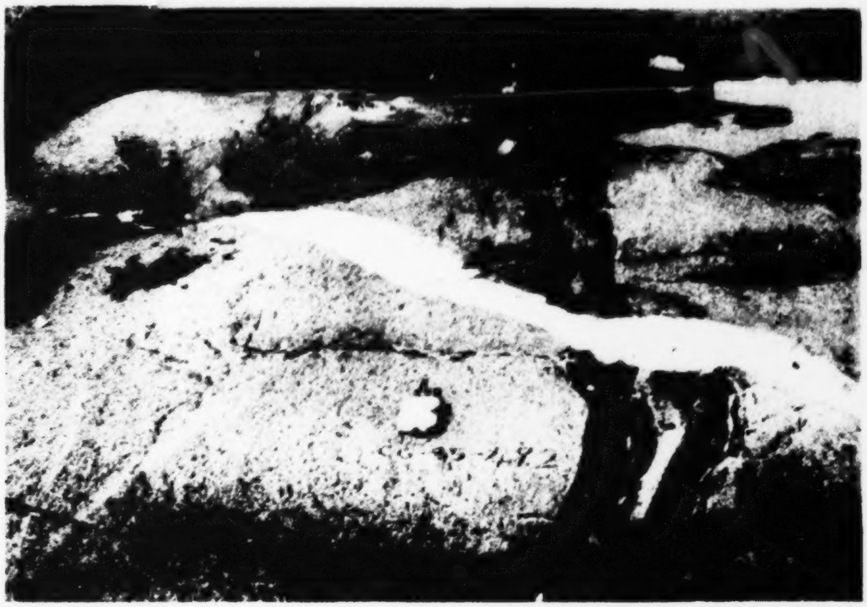

Plate 1: *Quartz diorite of the Domino domain intruded by early deformed mafic dike, later less deformed mafic dike (across top of photograph) and pegmatite which is severely attenuated in later mafic dike. Frenchmans Island area.*

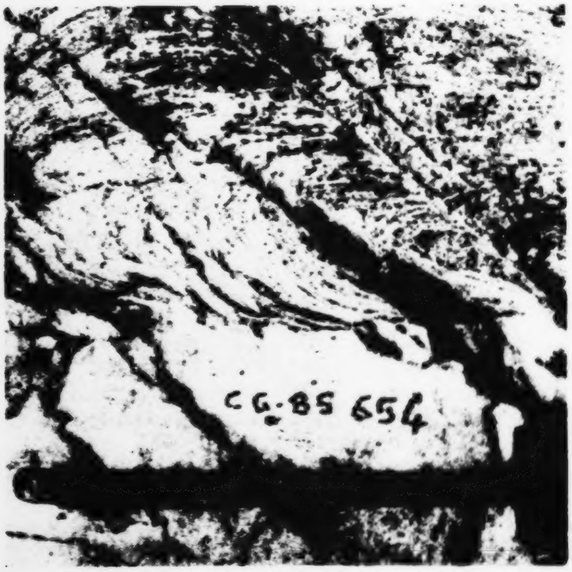

Plate 2: *Biotite granodiorite gneiss discordantly intruded by pink, muscovite-biotite granite. Elsewhere the granite is intruded by the later mafic dikes of Plate 1. Frenchmans Island area.*

Apart from the muscovite-biotite granite, most of the granitoid rocks appear to form an intergradational package. The granite, however, is probably later as it is intruded only by the later mafic dikes. Also, the granite is the only unit seen to unequivocally intrude orthogneiss (Plate 2). Assuming protolith equivalence between the other granitic plutonic rocks and the orthogneiss, it is thus inferred that granite postdates the migmatization which variably affected other granitoid units.

Layered mafic intrusive rocks in the Domino domain include gabbro, norite and minor troctolite, with leucocratic and melanocratic variants. Ultramafic rocks are a minor associated rock type. These rocks have either sharp or gradational contacts with associated diorite, monzonite and, locally, syenite. Layering is best seen in the more melanocratic units and is particularly well exposed on North Wolf Island (Figure 2). Gradations between the lower gabbroid part and the upper more felsic part of a layered unit commonly occur over a few metres and, if exposure is not perfect or if the rocks are deformed, the transition may not be observed. Contacts between the felsic top of one layered unit and the overlying base of the next are sharp, but many instances were seen where felsic material, identical to that in the underlying layered unit, has agmatitically invaded the overlying mafic rocks (Plate 3). These examples are interpreted to indicate that the lower layered unit was emplaced later and that the injected material is a late stage differentiate of the felsic part of the lower unit. No geochronology has been carried out on these layered mafic intrusions but a similar gabbro monzonite at Grady Island (40 km northeast of Cartwright) has been dated at 1610 ± 30 Ma (Brooks, 1983). It is suspected by the authors that these layered mafic intrusions will yield similar ages.

Typically, contacts between the layered mafic intrusions and their granitic hosts are tectonized, but chilled borders

Plate 3: *Agmatitic relationships between mafic rocks and monzonite at the base of a layered unit in a layered mafic intrusion. South of Batteau.*

at some localities clearly demonstrate that the layered mafic intrusions postdate at least some of the granitoid plutons. As most granitoid plutons in the Grenville Province in eastern Labrador have an age of ca. 1650 Ma (Gower and Owen, 1984; Gower and Ryan, 1986), the time interval between granitoid plutons and layered mafic intrusions need not have been great.

The main area of metasedimentary gneiss in the Domino domain is located south of Batteau (Figure 2). The rocks are well banded gneiss containing a muscovite-biotite-opaque mineral restite and a pink quartzofeldspathic leucosome. Garnet may be present in the restite and tourmaline occurs sporadically. Pods and more continuous layers of amphibolite probably represent former mafic dikes. Farther south, in the Frenchmans Island area, small isolated areas of sillimanite-bearing metasedimentary gneiss are found within granitoid rocks. These are interpreted by the authors as mega-enclaves that were enclosed by the granitoid plutons during emplacement.

The only radiometric dates presently available in the study area are from the Domino domain. Ages of 816 ± 19 Ma and 667 ± 19 Ma (K-Ar, whole rock) were obtained from mafic dikes, and an age of 944 ± 12 Ma (K-Ar, biotite) was obtained from a granitic intrusion (Grasty *et al.*, 1969). These ages have been adjusted from those originally reported using IUGS recommended decay constants (Steiger and Jager, 1977). The meaning of the dates on mafic dikes is difficult to evaluate without additional geochronology, but the 944 Ma date, which is similar to biotite ages reported elsewhere from the Groswater Bay terrane (see Gower and Ryan, 1986), probably reflects late-Grenvillian uplift and cooling.

Earl Island Domain

The Earl Island domain underlies most of the northern part of the Sand Hill River - Batteau map region. Comparable rocks to the north and west have been described by Gower *et al*. (1982, 1985). Within the map area, the two main rock types are biotite-hornblende diorite to quartz diorite and biotite granodiorite containing minor hornblende. These are similar in mineralogy, texture and fabric to analogous rocks in the Domino domain. Most of the granodiorite underlies the southern part of the Earl Island domain; dioritic rocks are more extensive farther north. This distribution is interpreted to mean that the granodiorite is a higher level rock type that has been infolded farther north to give the alternating pattern of elongate granodiorite bodies within diorite that is evident in Figure 2.

Small areas of granite and megacrystic granitoid rocks depicted in Figure 2 have similar mineralogical and textural characteristics to their counterparts in the Domino domain. As in the Domino domain, these rocks (except, perhaps some of the granite) are regarded by the authors merely as mineralogical variants of the diorite and granodiorite, rather than unrelated intrusions.

Other rock types in the Earl Island domain include mafic rocks and rare occurrences of metasedimentary gneiss. The mafic rocks consist of gabbro, amphibolite and melanocratic diorite, locally with norite and ultramafic units. Although these rocks tend to be resistant to erosion and form hills, exposure is not adequate to observe layering comparable to that in coastal localities. The rare occurrences of metasedimentary gneiss include muscovite- and sillimanite-bearing rock types, interpreted as enclaves within granitoid plutons of the Earl Island domain.

Paradise Metasedimentary Gneiss Belt

The Paradise metasedimentary gneiss belt underlies much of the southern half of the Sand Hill River - Batteau map region. Gradually tapering, it can be traced continuously northwestward for a further 80 km (Gower *et al*. 1982, 1985; Gower and Owen, 1984).

The dominant rock type is a sillimanite-biotite-cordierite pelitic or semipelitic gneiss, including areas of muscovite-rich pelitic gneiss and diatexite. Minor associated rocks include quartzite and/or lean banded iron formation, psammitic gneiss, calc-silicate rocks and amphibolite. The pelitic gneiss is pink and black, creamy, white or buff weathering, medium grained and well banded. All stages of migmatization are seen from pods of leucosome within a relatively homogeneous paleosome to dismembered rafts of restite in diatexite. Restite minerals include biotite, sillimanite, cordierite and opaque minerals. Garnet is an additional restite mineral but, in contrast to similar gneisses farther northwest, is somewhat rare. Relict kyanite is present in the central part of the map area.

Adjacent to the Sand Hill Big Pond gabbronorite, the metasedimentary gneiss has a buff, gray or brown weathering appearance (Plate 4), and lacks the well banded leucosome-restite contrasts that occur throughout the remainder of the area (see Metamorphism).

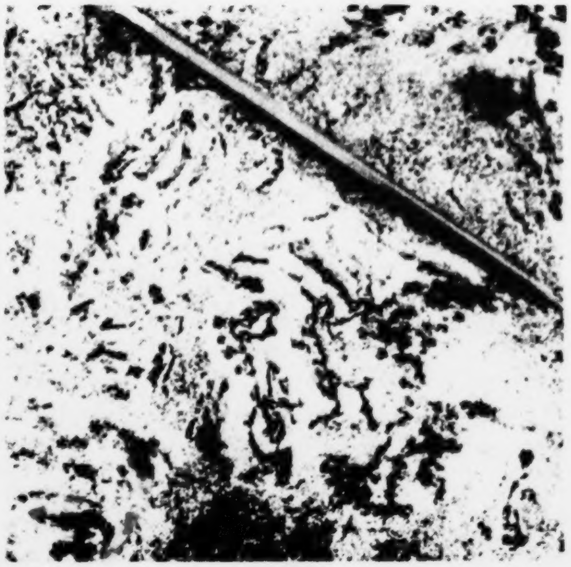

Plate 4: *Charnockitic pelitic gneiss adjacent to Sand Hill Big Pond gabbronorite. This unit locally is sapphirine bearing.*

The muscovite-rich metasedimentary gneiss is a schistose to well banded, fine to coarse grained, pink, white or gray rock that has a variably migmatized appearance. In places, the rocks show a fine lamination, which may reflect relict bedding, but elsewhere they have discontinuous lenses or patches of leucosome in a wispy or contorted restite. Commonly these rocks contain sillimanite. Without thin section assessment, it is uncertain whether the muscovite-rich metasedimentary gneisses are retrograde products of higher grade metamorphic assemblages, or if they indicate areas of lower grade metamorphism.

White weathering diatexite, interpreted as the product of extensive melting of pelitic gneiss, is most common in the south-central part of the study area. In contrast to similar rocks associated with metasedimentary gneiss in other parts of the Grenville Province of eastern Labrador, these rocks lack garnet, but instead commonly contain cordierite.

Other rock types in the Paradise metasedimentary gneiss belt are volumetrically minor. Quartzite, interbanded with calc-silicate rocks, correlates with a marked aeromagnetic anomaly 8 km northeast of Sand Hill Big Pond. Thinly bedded quartzite, associated with amphibolite, calc-silicate rocks and pelitic gneiss, occurs at several coastal localities. Calc-silicate rocks, consisting of a grossular/andradite-diopside-calcic plagioclase-quartz ± calcite assemblage, are generally present either as thin layers or boudinaged pods, and are not abundant. However, at one locality 9 km south of Comfort Bight, they are a major rock type, together with quartz-rich metasedimentary rocks, and form a section about 100 m thick (Plate 5). Amphibolite, similar to that discussed by Gower *et al.* (1985) as being of supracrustal origin, is exposed sporadically but, because of inadequate exposure, cannot be assigned to a specific protolith. It is certain (from field relationships and textural criteria) that amphibolite at some localities represents remnants of mafic dikes or larger intrusions although some amphibolite is probably of supracrustal origin. The metasedimentary gneisses are also characterized by pyritic zones and muscovite-bearing pegmatites (see Economic Mineral Potential).

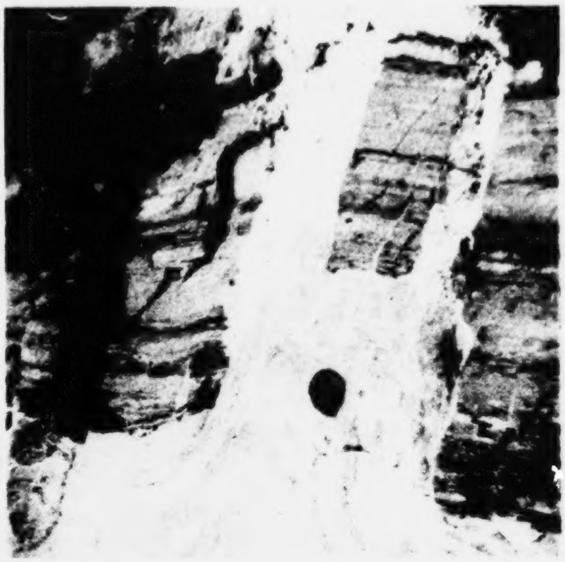

Plate 5: *The birth of a pegmatite in calc-silicate and quartzitic metasedimentary gneiss. South of Comfort Bight.*

An additional feature of the Paradise metasedimentary gneiss belt is the presence of granitoid plutonic rocks, which range in size from isolated outcrops to the moderate-size plutons found in the southeast part of the map region. The isolated outcrops comprise white, pink or gray weathering, medium to coarse grained, homogeneous, K-feldspar megacrystic and non-megacrystic granodiorite, granite and quartz diorite. Biotite is the characteristic mafic mineral but hornblende-bearing rocks are found in the central part of the study area.

The granitoid pluton in the southeast part of the map area is subdivided into a central zone of pink, medium to coarse grained, K-feldspar megacrystic, biotite granodiorite to granite, and an outer envelope of brown or gray weathering, medium grained quartz diorite. The K-feldspar megacrystic core is homogeneous, weakly foliated to massive and commonly contains enclaves of ultramafic, mafic and metasedimentary rocks. The outer envelope, although referred to as quartz diorite, also includes a broad range of dioritic and amphibolitic rock types, and the whole envelope has an inhomogeneous, moderately foliated to gneissic, migmatized appearance. It is evident that the core and envelope are spatially associated, and it can be demonstrated that the core of the pluton was emplaced after the migmatization that affected the outer envelope. Determination of petrogenetic relationships between the two units awaits more detailed study.

Sand Hill Big Pond Gabbronorite

Mafic plutonic rocks in the Sand Hill Big Pond area were first outlined by BRINCO Ltd. (Bradley, 1966; Donohue, 1966). The rocks include gabbro, leucogabbro, norite, leuconorite, troctolite and anorthosite, including minor occurrences of monzonite along the southwest flank of the unit. One of the most typical rock types is a dark weathering, coarse grained leuconorite containing large, black or gray, primary plagioclase and rusty brown orthopyroxene. Commonly, plagioclase is recrystallized at grain boundaries to white weathering granules. Rocks with less orthopyroxene or more olivine grade into anorthosite and troctolite respectively. In the olivine-bearing rocks, double hypersthene-pargasitic amphibole coronas are ubiquitous. Near its southern boundary, the Sand Hill Big Pond gabbronorite consists of much finer grained rocks that do not appear to be mineralogically distinct from their coarser grained counterparts. Very coarse grained rocks are also present—one locality southeast of Sand Hill Big Pond has pyroxene crystals up to 40 cm long.

Paradise Arm Pluton

The Paradise Arm pluton (Figure 2), previously thought to terminate at the eastern boundary of the Paradise River map area (Gower *et al.*, 1985), has now been traced across the Sand Hill River - Batteau map region, giving it a mapped length exceeding 110 km. The area where it was shown to pinch out (Gower *et al.*, 1985) was re-examined in more detail and, although the pluton narrows, it is now known to continue through without break.

The pluton is a homogeneous, white to pink, medium to coarse grained K-feldspar megacrystic rock, containing megacrysts that are between 1 to 7 cm in diameter and make up 5 to 35 percent of the rock. Partly because of variations in megacryst abundance, the rocks can be variably described as granodiorite, granite, monzogranite and syenogranite. Mafic minerals include biotite, hornblende and, more rarely, orthopyroxene and garnet. Locally, dioritic and/or metasedimentary gneiss enclaves are present but most of the pluton is free of xenolithic material.

The Paradise Arm pluton is interpreted here to postdate the Sand Hill Big Pond gabbronorite and the White Bear Arm complex, and it is suggested here that these two units were contiguous prior to emplacement of the Paradise Arm pluton along a linear zone of weakness.

White Bear Arm Complex

The mafic rocks that underlie the southeast corner of the Sand Hill River - Batteau map region are part of the White Bear Arm complex (WBAC), a major plutonic body that extends from Paradise River to Square Islands, a distance of 150 km. Within the map region, the White Bear Arm complex consists of gabbro, norite, minor troctolite and their leucocratic variants. The rocks are fine to medium grained, dark gray, black or rusty weathering, homogeneous, and massive, and have partially or completely preserved igneous textures. Commonly, the mafic rocks are injected by buff-pink, fine to medium grained monzonite in an anastomosing or agmatitic fashion.

Late Precambrian - Early Paleozoic Mafic Dikes

Three major, and one minor, north-northeast-trending mafic dikes were mapped in the study area. The major dikes consist of black or brown weathering, coarse grained, ophitic-textured gabbro containing interstitial K-feldspar and partially hydrated mafic silicates.

The two western dikes are on line with intrusions mapped in coastal areas 25 km east of Cartwright (Eade, 1962; Gower *et al.*, 1982; Owen *et al.*, 1983). Assuming the dikes in the study area are direct extensions of those on the coast, both dikes would have a strike length of about 75 km. The dike in the north-central part of the map region was previously unknown. It is exposed on Sand Hill River and is clearly visible on aerial photographs.

On the coast, the western dike has been dated at 553 ± 22 Ma (K-Ar, biotite, Wanless *et al.*, 1970). The co-ordinates originally reported for the dated sample were given erroneously as 53° 44′ N, 56° 49′ W. This is the location shown by Owen *et al.* (1983), who did not locate the dike, but assumed that it existed as indicated and was simply missed during 1:100,000 scale mapping. When the dike could not be found during re-examination of the area (M. Tubrett, personal communication, 1985), the quoted location was queried and found to be incorrect. The correct co-ordinates are 53° 46′ N, 56° 38′ W on Cartwright Island (W.D. Loveridge, personal communication, 1985).

The minor dike, approximately 1 m wide, was found at two localities in the Porcupine Bay area (Figure 2). A dike of similar width and appearance occurs directly along strike, on the north side of Hawke Bay, some 35 km to the south. Although these dikes are widely separated, the persistence over considerable distances of similar, albeit larger dikes farther west may indicate that these minor dikes were injected along a common line of weakness.

Structure

The structure of the map region is dominated by a prevalent west-northwest to northwest trend which affects all rocks except the late Precambrian - early Paleozoic mafic dikes. Foliation and gneissosity are moderately to steeply inclined and the majority of dips are to the southwest. Measured lineations do not show any consistent plunge direction except those associated with a thrust north of Porcupine Bay. Evidence for minor, tight to isoclinal folding is ubiquitous, especially in the metasedimentary gneiss. Large folds were identified in places (Figure 2).

The thrust north of Porcupine Bay has an approximate southward dip of 45°. It is marked by a broad zone of well banded gneiss, mylonite and ultramylonite (Plate 6). Rotated K-feldspar porphyroclasts indicate northward transport of the hanging wall. A mylonite zone 15 km to the west, but roughly on strike with that near Porcupine Bay, may be a continuation of the same structure. However, no severely mylonitized rocks were observed at shoreline exposures between the two areas of mylonite.

Mylonite is also associated with a series of northwest-trending strike-slip faults. In addition to mylonite zones, these are further defined by marked photolineaments and straight

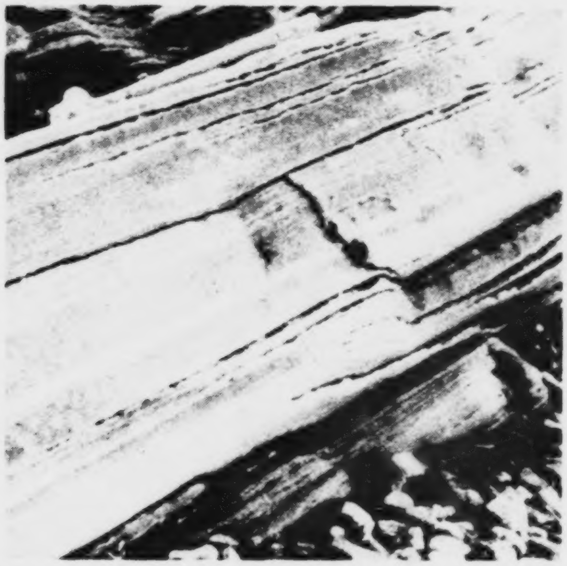

Plate 6: *Mylonite from thrust zone southwest of Batteau.*

valleys. Other well defined, parallel photolineaments suggest that additional similar faults may be present, for which field evidence is presently lacking. These faults are anticipated in the structural model outlined for the Lake Melville terrane by Gower *et al.* (1985).

In addition to the structures outlined above, there is a well defined pattern of east-northeast- and west-northwest-trending photolineaments. These correlate with aeromagnetic features and some are known to be associated with zones of hematite alteration. The east-southeast- trending photolineaments are interpreted as sinistral faults, which have, in places, offset the boundary between the Earl Island domain and the Paradise metasedimentary gneiss belt.

No direct information is available for the north-northwest-trending photolineaments. However, the two trends are bisected by the late Precambrian - early Paleozoic mafic dikes. Such a pattern (whereby the photolineaments represent shear directions and the mafic dikes are a bisecting tensional direction) is compatible with a stress regime proposed by Gower *et al.* (1986) to explain post-Grenvillian events, including the formation of the Lake Melville and Sandwich Bay graben, and emplacement of north-northeast-trending mafic dikes.

Metamorphism

Metamorphic grade in the map region is amphibolite to granulite facies. The granulite facies assemblages are best developed in the southwest part of the region.

In the Earl Island and Domino domains, assemblages containing epidote, allanite and sphene are ubiquitous in the dioritic and granodioritic rocks, and garnet occurs sporadically. The presence of epidote, allanite and sphene is characteristic of the Groswater Bay terrane, whereas these minerals are absent in much of the Lake Melville terrane. The metasedimentary gneiss enclaves in the Earl Island and Domino domains are mostly muscovite bearing, but sillimanite was found in the Frenchmans Island area. Double coronas of hypersthene and pargasitic amphibole mantle olivine in mafic rocks in the Domino domain.

Pelitic gneiss in the Paradise metasedimentary gneiss belt is characterized by K-feldspar-plagioclase-quartz-opaque minerals ± biotite ± cordierite ± sillimanite ± kyanite ± garnet ± orthopyroxene ± sapphirine assemblages. Sillimanite and cordierite are ubiquitous, and, typically, the cordierite is partially or completely pseudomorphed by biotite and sillimanite. Garnet is uncommon but occurs sporadically throughout the map area, except in the metasedimentary gneisses flanking the Sand Hill Big Pond gabbronorite and the Paradise Arm pluton. Kyanite is a relict mineral presently known only from the central part of the map region.

Orthopyroxene and sapphirine are restricted to the metasedimentary gneiss adjacent to the Sand Hill Big Pond gabbronorite and the Paradise Arm pluton. This gneiss has a distinct appearance in the field (Plate 4), is depleted in hydrous mafic silicates and garnet, and contains abundant magnetite. Sapphirine occurs at five localities in three areas close to the gabbronorite (Figure 2). These occurrences mark the first discovery of sapphirine in the Grenville Province of eastern Labrador. It is suggested here that the orthopyroxene- and sapphirine-bearing rocks document a high-pressure and high-temperature aureole adjacent to the Sand Hill Big Pond gabbronorite.

In the Sand Hill Big Pond gabbronorite and the White Bear Arm complex, igneous mineral assemblages and textures are widely preserved, except in mylonite zones. Double hypersthene-pargasitic amphibole coronas mantle primary olivine in both bodies.

Economic Mineral Potential

Assessment of the economic mineral potential of parts of southeastern Labrador was carried out by BRINCO Ltd. in 1954 and 1965. The later phase of activity included stream sediment geochemical sampling, and prospecting and geological mapping of selected areas. Although traces of base metal mineralization were discovered, and several geochemical anomalies were identified, exploration was discontinued.

From the present study and previous work (Gower and Erdmer, 1984; Gower *et al.*, 1985), the metasedimentary gneiss appears to have the highest economic potential. Sulfide zones (mainly pyrite) are common, especially in the better exposed coastal areas (Figure 3). One of these, at Mountaineer Cove near the entrance of Hawke Bay, was described by Douglas (1953, pages 12 and 13) as '...having a width of about 100 ft. and an unknown length.' He reported analyses of three samples for Fe, U and Th, which gave a range of 16.75 to 25.94 percent Fe, and 'nil' values for U and Th. Samples collected from this occurrence, and other localities during the present mapping, have been analyzed for Au; the results are indicated in Figure 3.

Eade (1962) also noted two pyritic showings in metasedimentary gneiss. One of his localities was found during the present study in the course of a brief helicopter

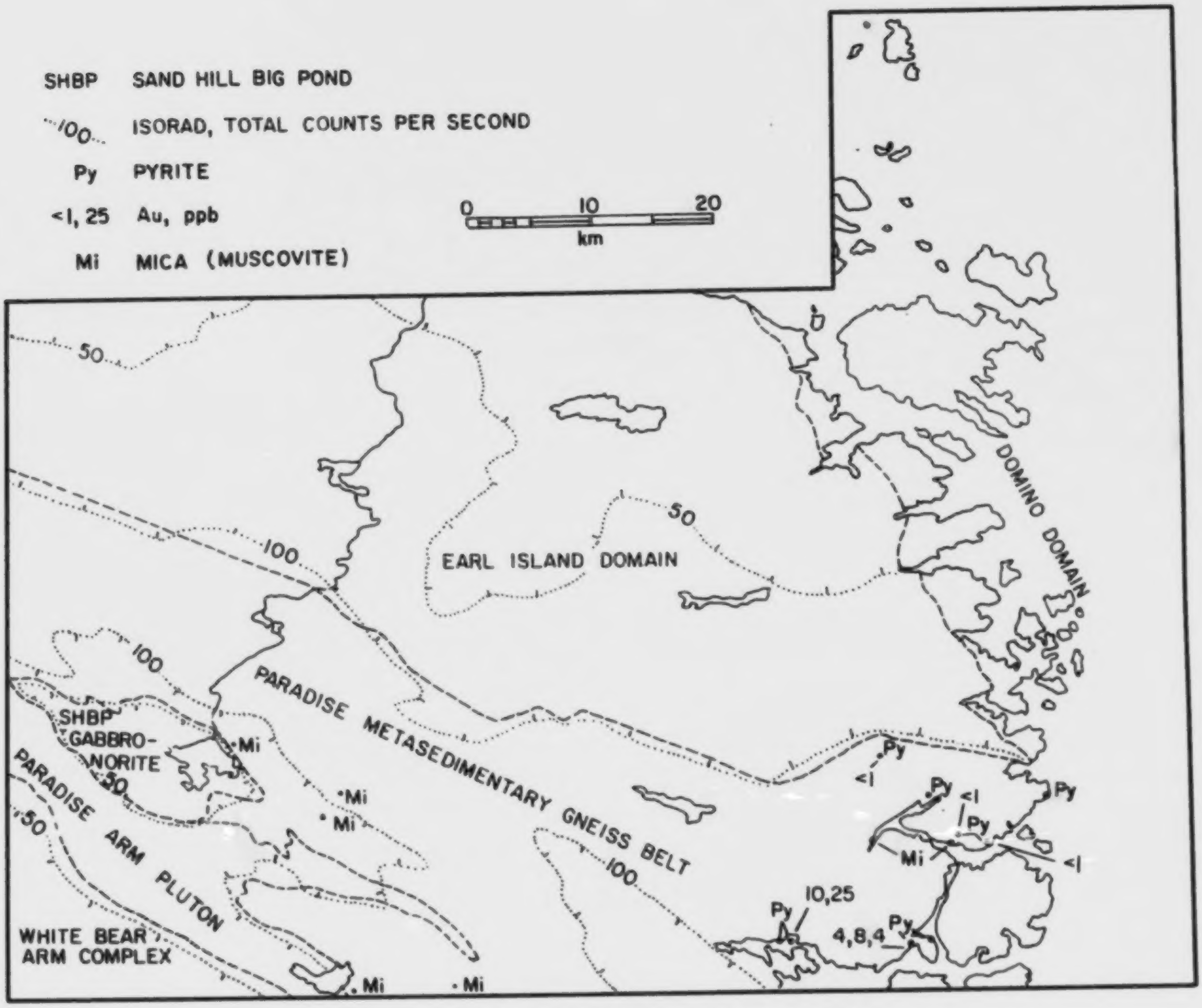
SHBP SAND HILL BIG POND
100 ISORAD, TOTAL COUNTS PER SECOND
Py PYRITE
<1, 25 Au, ppb
Mi MICA (MUSCOVITE)
0 10 20
km
50
100
EARL ISLAND DOMAIN
DOMINO DOMAIN
PARADISE METASEDIMENTARY GNEISS BELT
SHBP GABBRO-NORITE
PARADISE ARM PLUTON
WHITE BEAR ARM COMPLEX
Mi
Py
<1
10,25
4,8,4

Figure 3: *Economic mineral potential map for the Sand Hill River - Batteau map region.*

search. Interestingly, the showing is roughly along strike with three other pyritic zones discovered during the present mapping. As none of these showings have been traced out for any distance, it is conceivable that detailed mapping would demonstrate that they belong to a single horizon.

Another showing, discovered during the present study, forms most of a small island near the north side of inner Hawke Bay. It gave the highest Au values obtained (albeit still background).

Muscovite-bearing pegmatites are also a characteristic feature of the metasedimentary gneiss. Only those localities where muscovite books exceed 5 cm in diameter are indicated in Figure 3. At several localities the books are considerably larger and reach 28 cm in diameter in one pegmatite (53°0.5'N, 56°36'W). The pegmatite is 10 m wide and has an exposed strike length of 50 m. It appears to be devoid of other minerals of potential economic interest.

Possibilities also exist for Ni-Co-Cr-Cu mineralization associated with the layered mafic intrusions and LIL mineralization associated with granitoid rocks. Douglas (1953) described a 20 m wide, Cu-bearing, magnetite-rich band in mafic rocks near Domino. Although no anomalous radioactivity was encountered in the map region (in contrast to previously mapped areas in eastern Labrador), anomalous Th has been reported (Kranck, 1966) from granitoid rocks in the area that are now mapped as part of the Paradise Arm pluton. Background scintillometer readings (see generalized contours in Figure 3) show high values over the Paradise metasedimentary gneiss belt and low values corresponding with the mafic intrusions. The distinction between the diorite and granodiorite of the Earl Island domain is also evident.

ACKNOWLEDGEMENTS

We thank Samson and Harris Learning of Paradise River and Jim Holwell of Spotted Island for their hospitality and help. Sealand Helicopters, through their pilots Al Piché and Ted Hay, provided excellent helicopter support and Newfoundland Air Transport similarly provided reliable fixed wing aircraft service through their pilot Norman Denis. Ken O'Quinn and Wayne Tuttle maintained efficient expediting services from Goose Bay. This manuscript was reviewed and improved by John McConnell and Andrew Kerr.

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GEOLOGY OF THE GOOSE BAY - GOOSE RIVER AREA

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Labrador Mapping Section

ABSTRACT

The map area lies within the interior Grenville Province and contains the southern part of the Cape Caribou River allochthon and its surrounding rocks. Potentially, the oldest rocks in the area are tonalitic-granodioritic gneiss of plutonic derivation, infolded with sillimanite metasedimentary gneisses and intruded by megacrystic granitoid. The gneisses are overthrust by the Cape Caribou River allochthon, a layered structural slice consisting of a lower unit of granitoid gneiss, and an upper sequence of metagabbroid rocks and anorthosite (North West River anorthositic intrusive suite). These are intruded by a variety of monzonitic, syenitic and granitic rocks (Dome Mountain intrusive suite) which pass westward into extensive foliated granites, syenites and derived gneisses, referred to as the Lower Brook metamorphic suite. The metamorphic suite has been thrust northward over the tonalite-granodiorite gneisses and megacrystic granite.

Absolute ages in the area are uncertain. The tonalite-granodiorite gneisses are thought to be of circa 1650 Ma age, but this may be an oversimplification. There is limited evidence suggesting that intrusion of the North West River, Dome Mountain and Lower Brook suites postdated early fabric development in the gneisses, but were deformed and metamorphosed in a later event.

The drift covered, southeastern part of the map area is inferred to underlie the western termination of the late Precambrian-early Paleozoic Lake Melville graben.

INTRODUCTION

This is the initial report for a new project started in 1985 on the geology of the interior Grenville Province in the Goose Bay region (Figure 1). As such, the project represents a southerly continuation of previous Department of Mines and Energy mapping projects by Ryan *et al*. (1982) and Wardle and Ash (1984).

The map area (Figures 2, 3) is centred on the towns of Goose Bay and Happy Valley, located at the western end of Goose Bay, which opens into Lake Melville (Figure 2). The towns, which benefit from regular coastal boat and commercial airline service, provide centres of road access to much of the map area. More remote parts are best reached by the chartered helicopter or float plane service available in Goose Bay.

The area is divided into a lowland plain, which surrounds Goose Bay and extends along the lower reaches of the Goose, Churchill and Peters rivers, and an undulating upland plateau deeply dissected by the same rivers. The lowland plain is thickly wooded and blanketed by glacial outwash sands and esturine clays (Kindle, 1924). The plateau is more thinly wooded and, with the exception of areas underlain by anorthosite, poorly exposed through a thick mantle of till and glaciofluvial material.

Geological aspects of the map area, notably the surficial deposits and the outcrops around Muskrat Falls (Figure 3), received early mention by Low (1897) and Kindle (1924). The area was examined in reconnaissance fashion by Scott and

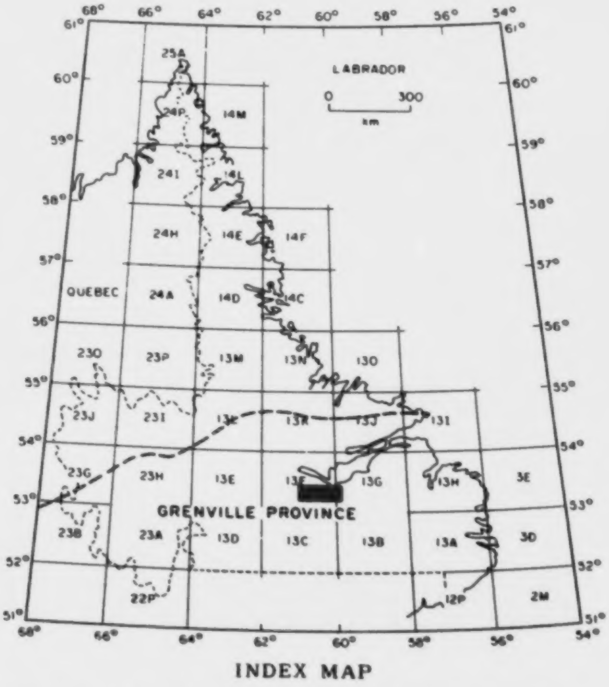

Figure 1: *Location of map area within Grenville Province of Labrador.*

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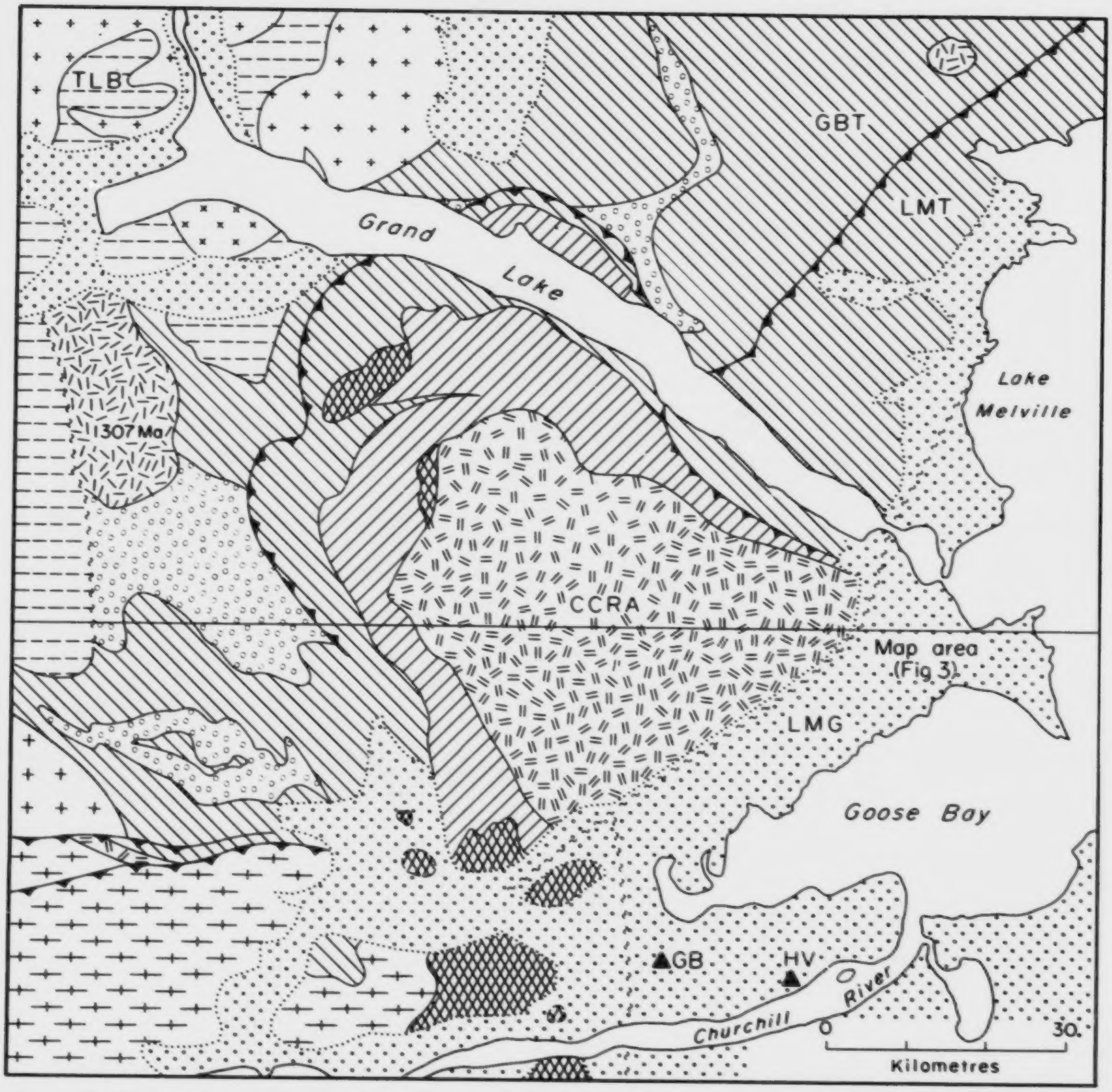


Figure 2: *Regional geology of the Goose Bay area. Simplified after Ryan et al. (1982), Wardle and Ash (1984), and Erdmer (1984). LMT - Lake Melville terrane; GBT - Groswater Bay terrane; CCRA - Cape Caribou River allochthon; TLB - Trans-Labrador batholith; GB - Goose Bay; HV - Happy Valley.*

Conn (1949) as part of a photogeological interpretation of the Goose Bay region, followed by Fulton and Hodgson (1969) who included the map area in their description of the surficial geology of the region. The bedrock geology of the area was not systematically mapped until it was included in the regional, 1"=4 miles, reconnaissance mapping program of Stevenson (1967).

GENERAL GEOLOGY

The geology of the Goose Bay region, as simplified from Ryan *et al.* (1982) and Wardle and Ash (1984 and this report) is summarized in Figure 2. The major feature of the region is the Cape Caribou River allochthon (CCRA), a layered, lobate, structural slice consisting of a lower unit of mylonitic tonalite-granodiorite gneiss (locally orthopyroxene bearing), and an upper sequence of metagabbroid-amphibolite and anorthosite referred to in this report as the North West River anorthositic intrusive suite. The allochthon is underlain by tonalitic-granodioritic gneisses that are generally banded and migmatitic, and infolded with belts of kyanite- and sillimanite-bearing metasedimentary gneiss.

The granitoid gneisses in the northeastern part of the region are divided by a major northeast-trending thrust. Gneisses lying northwest and southeast of the thrust are correlated respectively (Wardle and Ash, 1984) with the Groswater Bay and Lake Melville terranes of Gower (1984),

LEGEND

⁙ Pleistocene drift.

PROTEROZOIC

▦ Late monzonite-syenite gabbro intrusions.

+ Granite-quartz monzonite plutons.

⊞ Megacrystic granite.

⊠ Metadiorite.

┼ Lower Brook metamorphic suite: granite and granitic gneiss.

▩ Monzonite-syenite-granite intrusions (including Dome Mountain intrusive suite).

NORTH WEST RIVER ANORTHOSITIC INTRUSIVE SUITE

⫽ Anorthosite.

▨ Metagabbroid rocks locally layered.

☰ Foliated to gneissic quartz diorite (Susan River quartz diorite).

∘ Metasedimentary gneiss.

▧ Banded, migmatitic, quartz diorite-tonalite-granodiorite gneisses.

Gower and Owen (1984) and Erdmer (1984). Gneiss in the Groswater Bay terrane has been dated at 1680 Ma (Krogh *in* Erdmer, 1984) although it is uncertain as to whether this represents the age of metamorphism or protolith intrusion. Use of the terms Groswater Bay and Lake Melville terranes has, to date, not been extended southeast of the Cape Caribou River allochthon. However, Ryan *et al*. (1982) have described extensive areas of foliated to gneissic quartz diorite (their Susan River quartz diorite) and associated banded, migmatitic, granitoid gneisses, which in general appearance are remarkably similar to rocks of the Groswater Bay terrane.

The Susan River quartz diorite and associated granitoid gneisses are intruded by a variety of deformed granitoid plutons which, in the northwestern corner of the area shown in Figure 2, form part of the Trans-Labrador batholith of 1650-1500 Ma age (Gower and Owen, 1984). Some younger, less deformed, stocks of gabbro, monzonite and syenite also intrude the gneisses and have been dated at one locality at 1307 28 Ma (Fryer *in* Ryan *et al*., 1982).

The southwestern part of the region (Figure 2) comprises a suite of granitic gneisses, informally named here the Lower Brook metamorphic suite, which is thrust over the gneisses and megacrystic granitoid to the north. The suite preserves relicts of granulite facies metamorphism and locally intrudes the gray, tonalite-granodiorite gneisses.

The drift covered lowlands around Goose Bay have recently been interpreted by Gower *et al*. (*in press*) to form the western end of the late Precambrian - early Paleozoic Lake Melville graben.

Gneisses (Units 1 and 2)

Gray, granitoid gneisses of tonalite-quartz diorite-granodiorite composition (Unit 1). This unit, exposed largely in the northwestern part of the map area, is texturally and compositionally heterogeneous, ranging from hornblende quartz diorite gneiss to hornblende-biotite tonalite and granodiorite gneiss. All types locally contain garnet and are interbanded with amphibolite and amphibolite gneiss, which is locally scapolite bearing. An area of relatively homogeneous, well foliated to weakly gneissic, quartz diorite, which outcrops in the extreme northwest corner of the map area, is designated as subunit 1gd (Figure 2) and forms part of the extensive Susan River quartz diorite of Ryan *et al*. (1982). The Susan River quartz diorite, where locally gneissic, is indistinguishable from many of the gneisses grouped in Unit 1 of this report, but is not necessarily of the same age.

An isolated outcrop area of granitoid gneiss occurs south of the Peters River (subunit 1c) where it is partly enclosed by the younger granitic rocks of Unit 10. These gneisses are strongly banded and migmatitic, generally more so than most of Unit 1, and contain a pink to white, pegmatitic, granite leucosome.

Sillimanite metasedimentary gneiss (Unit 2). Metasedimentary gneiss is disposed in belts infolded with granitoid gneiss in the northwestern part of the area but also occurs as small outcrops in subunit 1c and Unit 10. The metasedimentary gneisses are pink to gray weathering, strongly migmatitic with a pink, pegmatitic, granite leucosome, and are generally tightly folded. They contain the overall assemblage quartz+feldspar+biotite+sillimanite+magnetite/ilmenite garnet. Secondary muscovite is usually present in varying amounts.

The small outcrop area within subunit 1c consists of a similar metasedimentary gneiss but also contains pods of garnet-biotite amphibolite, interpreted as relict dikes.

Plate 1: *Dike of gneissic granodiorite in sillimanite metasedimentary gneiss of Unit 2; lens cap is 5 cm in diameter.*

Contacts between metasedimentary gneiss and adjacent units have not been seen. An exposure on the Goose River shows a dike of gneissic granodiorite intruding metasedimentary gneiss (Plate 1), which may indicate an intrusive relationship with at least part of Unit 1. The relatively massive nature of the dike suggests that it may postdate development of the migmatite texture in the host gneiss, however, confirmatory cross-cutting relationships have not been observed.

North West River Anorthositic Intrusive Suite (Units 3 and 4)

Metagabbroid - amphibolite (Unit 3). This unit forms the southwestern limb of a horseshoe-shaped rim of metagabbroid rocks that partially enclose, and also underlie, the anorthosite of Unit 4 (Ryan *et al.*, 1982; Wardle and Ash, 1984). Within the map area, the gabbroid rocks vary from massive to layered in texture and become progressively recrystallized to amphibolite away from the anorthosite. Relict, primary orthopyroxene is locally preserved within metamorphic assemblages of hornblende+plagioclase+clinopyroxene ± garnet. The metagabbroids-amphibolites are also intruded by abundant dikes and sheets of gray monzonite, syenite and granite assigned to Unit 7 (Plate 2), such that 50 percent or more of any outcrop area is likely to consist of granitoid. Ultramafic rocks, generally hornblendites, occur as local enclaves within granitoids of Unit 7 and are presumed to have been part of Unit 3.

Plate 2: *Foliated leucogabbroid (L) of Unit 3, intruded by foliated sheets of Unit 7 monzonite (M); notebook is 19 cm long.*

The granitoid dikes and sheets generally intrude parallel to the foliation in Unit 3, and appear to be deformed together with that unit. However, at one locality (Plate 3) a foliated monzonite dike contains xenoliths of amphibolite with a strong fabric that clearly predates monzonite intrusion.

Anorthosite (Unit 4). Anorthosite occurs as an extensive massif within the centre of the Cape Caribou River allochthon, and also as a small sliver south of the Peters River, near the western margin of the map area. The part within the allochthon typically comprises coarse to very coarse grained anorthosite and leucogabbroid. Mafic minerals include olivine, orthopyroxene and varying amounts of magnetite and ilmenite. The leucogabbroids locally contain primary olivine, clinopyroxene and orthopyroxene and have compositions ranging from olivine leucogabbro to leuconorite. However, many primary mafic minerals, particularly olivine, are extensively recrystallized to coronal textures with rims of orthopyroxene and symplectic spinel, and are partially replaced by amphibole-biotite intergrowths. More advanced alteration involves recrystallization to secondary clinopyroxene-amphibole assemblages, with the result that the original gabbroid rock type is difficult to identify.

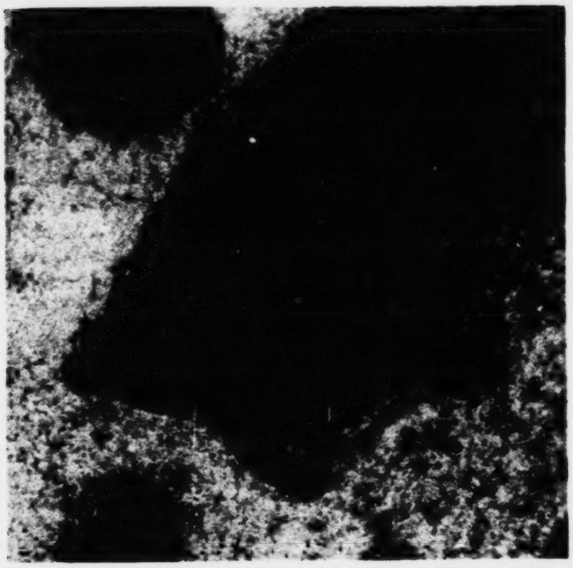


Plate 3: *Xenolith of foliated or lineated amphibolite of Unit 3 in Unit 7 monzonite (the monzonite is strongly sheared to left of picture); lens cap is 5 cm in diameter.*

Layering is commonly present near the contact with Unit 3 where leucogabbroid alternates with anorthosite. Anorthosite in this zone is generally enriched in magnetite. Also, leucogabbroid commonly occurs as elipsoidal pockets within anorthosite, a feature that occurs throughout the unit, but is particularly prevalent near its margins and it is interpreted to result from late-stage crystallization of intracumulate magma pockets. Anorthosite and leucogabbroid generally possess a strong igneous lamination defined by pyroxene and plagioclase.

Igneous texture is generally well preserved within unit 4 and deformation is restricted to narrow mylonitic shear zones. However, large areas of anorthosite near the western margin of the unit are partially recrystallized to a texture in which large, rounded, elongate relicts of giant primary plagioclase crystals 'float' in a matrix of finer grained, secondary plagioclase and variably altered mafic minerals (Plate 4).

The anorthosite is intruded by numerous metagabbroid dikes, which locally retain chilled margins, but are also extensively recrystallized and folded.

The southwestern contact of Unit 4 is a sharp but gradational contact with Unit 3. The anorthosite is also intruded by dikes of monzonite, granite and pegmatite which are generally similar to those intruding Unit 3.

The small, western sliver of anorthosite is more strongly deformed than the bulk of Unit 4, and it is largely recrystallized to a streaky, banded rock composed of secondary, white plagioclase, and amphibole (Plate 5). Locally, however, a coarse grained texture is preserved as well as the elipsoidal leucogabbroid pockets typical of the main body. The sliver is also similarly intruded by deformed granitoid and pegmatite dikes.

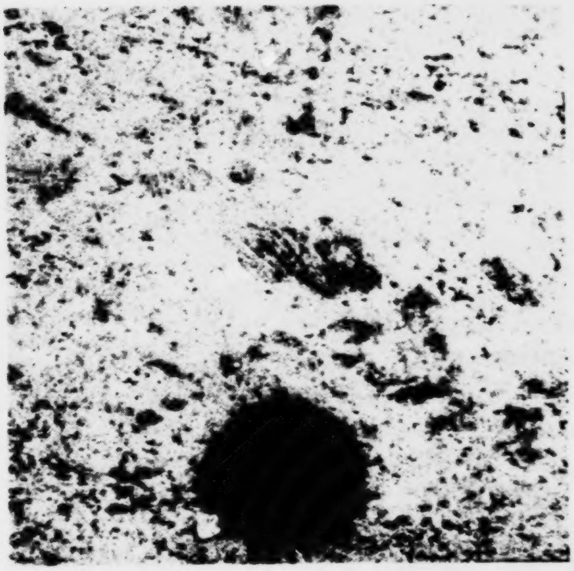


Plate 4: *Recrystallized, coarse grained anorthosite of Unit 4 containing relicts (dark crystals) of giant, primary plagioclase crystals; lens cap is 5 cm in diameter.*

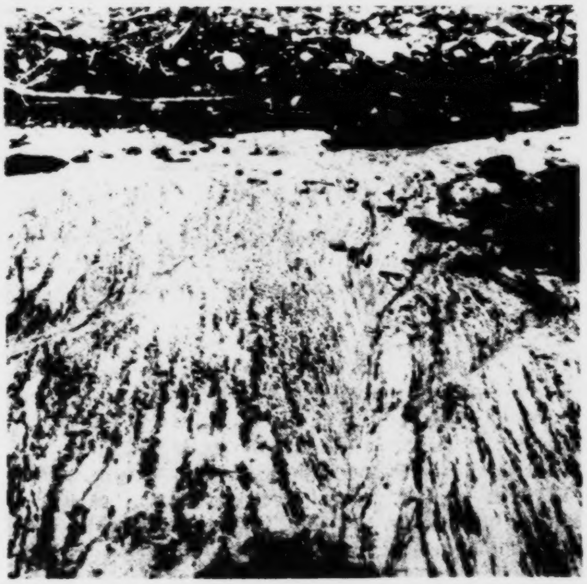
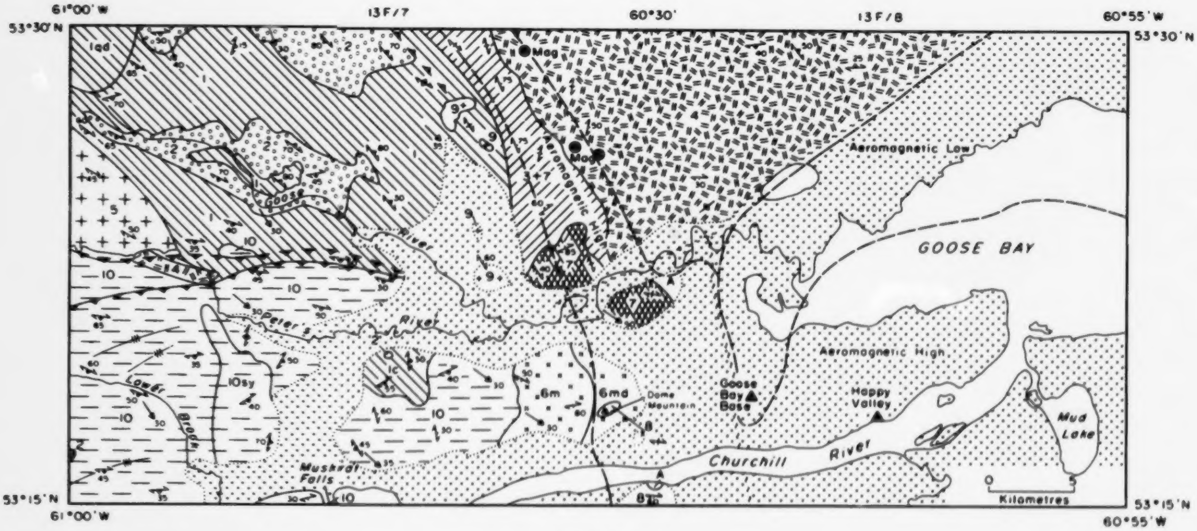


Plate 5: *Strongly foliated and recrystallized, coarse grained anorthosite in the sliver of Unit 4 near the western margin of the map area; hammer is 34 cm long.*


61°00'W
13F/7
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13F/8
60°55'W
53°30'N
53°30'N
53°15'N
53°15'N
61°00'W
60°55'W
1qd
Goose
Moo
Aeromagnetic Low
GOOSE BAY
Aeromagnetic High
Peter's River
Lower Brook
10sy
10
6m
6md
Dome Mountain
Goose Bay Base
Happy Valley
Mud Lake
Churchill River
Muskrat Falls
0
5
Kilometres

LEGEND

PROTEROZOIC

☰ Foliated, pink granite and granite gneiss; 10sy, syenite and syenite gneiss; includes abundant amphibolite and gray, granitoid gneiss enclaves.

+ Miscellaneous, small granitoid intrusions.

Dome Mountain intrusive suite (Units 6 to 8)

☐ Buff, alkali-feldspar granite, syenite and quartz syenite.

▩ Purplish-gray, inequigranular monzonite.

× 6qm, gray, equigranular quartz monzonite to monzonite; 6md, purplish-gray, equigranular to inequigranular, quartz monzodiorite to monzodiorite.

+ Gray, megacrystic granitoid.

A Amphibolite-metagabbroid enclaves in younger rocks.

North West River anorthositic intrusive suite (Units 3 and 4)

⁂ Coarse grained anorthosite-leucogabbroid.

▨ Metagabbroid-amphibolite, locally layered, containing minor hornblendite.

⁘ Sillimanite metasedimentary gneiss.

▧ Gray, granitoid gneiss of tonalite-granodiorite composition containing abundant amphibolite and amphibolite gneiss; 1qd, well foliated to weakly gneissic quartz diorite; 1c, well banded, migmatitic, granitoid gneisses.

Figure 3: *Geology of the Goose Bay - Goose River area.*

Amphibolite-metagabbroid (Unit A). Amphibolites and metgabbroids are present as inumerable enclaves of widely varying size within the granitoid rocks of Units 6 to 10. Although only a few of these are large enough to be shown on Figure 3, they nevertheless form an important component which constitutes up to 50 percent of the area indicated as granitoid on Figure 3.

Amphibolite of plagioclase-hornblende garnet composition is the prevalent rock type, typically containing irregular lenticles and seams of hornblendite. Metagabbroid rocks, including leucogabbroid, have ophitic texture and local layering, and grade into amphibolite. Primary pyroxene and rare olivine is also preserved. Ultramafite in the form of hornblendite is a lesser constituent of this unit.

The amphibolites and metagabbroids (Unit A) forming enclaves in Units 6, 7 and 8 appear to be derived from a pre-existing gabbroid plutonic suite. In overall composition and appearance they are similar to rocks of Unit 3, and it is thought that they may represent a southward continuation of Unit 3 that was largely engulfed by granitoid intrusions. This is supported by the aeromagnetic map of the area (GSC, 1970; see also Figure 3), which shows a pronounced, linear, positive anomaly projecting along the strike of Unit 3 southeastward into the Dome Mountain - Goose Bay area. The style in which the metagabbroid rocks of Unit 3 have been intruded by granitoid rocks is also suggestive of stoping, a process which would lead readily to incorporation of large amounts of mafic material into the granitoid plutons.

Amphibolite and metagabbroid rocks within Unit 10 are also locally similar to those seen in Unit 3 but are in general more strongly foliated or gneissic and locally preserve granulite facies metamorphic assemblages. The presence of the anorthosite sliver enclosed within Unit 10 suggests that some of the amphibolite enclaves may derive from associated gabbroid rocks; however other origins are possible including derivation from the gneisses of Unit 1.

Megacrystic granitoid (Unit 5). This unit occupies a triangular area on the western margin of the map area and is a gray, strongly foliated granitoid containing K-feldspar megacrysts set in a matrix of biotite, quartz, plagioclase and minor garnet. Composition varies from granodiorite to granite depending upon the proportion of megacrysts present. Where strongly foliated, the unit becomes an augen gneiss but migmatite texture was not observed. Minor amounts of non-megacrystic granite and amphibolite are also present within the unit.

The contact between Unit 5 and Unit 1, which is exposed in stream valleys on the south side of the Goose River valley, appears transitional and is defined by a gradual disappearance of megacrysts over a distance of several metres. The indistinct nature of the contact is probably due to the general similarity of composition between Unit 1 gneisses and the matrix of the megacrystic granitoid.

Dome Mountain Intrusive Suite (Units 6, 7 and 8)

Monzodiorite, monzonite and quartz monzonite (Unit 6). This unit, as is the case with all components of the Dome Mountain intrusive suite, is heterogeneous with regard to rock type and structure. The western part of the unit (subunit 6qm) is composed predominantly of gray, medium grained, equigranular, hornblende-biotite quartz monzonite and monzonite that are intruded by various types of white to pink granite and pegmatite, including minor amounts of K-feldspar megacrystic granitoid. Rocks vary from massive to foliated (and lineated) and exhibit local zones of incipient migmatization.

The eastern component of Unit 6 (subunit 6md) is largely a purplish-gray, medium grained, hornblende quartz-monzodiorite to monzodiorite characterized by an irregularly developed, weakly porphyritic texture of large K-feldspar crystals set in a dioritic matrix. This unit is also intruded by fine grained monzonite, granite and pegmatite, but is generally less deformed than the western part of Unit 6. Subunit 6md also incorporates several enclaves of a dark, purplish-gray amphibolite containing purple-gray plagioclase and plentiful biotite. These are interpreted as diorites but it is unclear whether they are part of the monzodiorite intrusion or metasomatically altered amphibolites of Unit A.

Monzonite (Unit 7). Monzonite occurs as two separate bodies north and south of the Goose River. It is also compositionally heterogeneous with the predominant rock type being a medium to coarse grained, purplish-gray, inequigranular, hornblende-pyroxene monzonite. Orthopyroxene was identified in one sample; in others, clinopyroxene partially altered to intergrowths of biotite, amphibole, quartz and opaque minerals is the predominant mafic phase, in association with hornblende. K-feldspar forms large crystals, 1 to 2cm in diameter, imparting an inequigranular texture to the rock. The monzonite is also associated with lesser amounts of buff syenite, gray to pink granite, and coarse grained to megacrystic alkali-feldspar granite.

The northern contact of Unit 7 with Unit 3 is of an irregular, interfingering nature, and its position as shown on Figure 3 is very approximate. Dikes and irregular masses of monzonite, syenite and granite that occur throughout Unit 3 are assigned to Unit 7, although they may also include correlatives of other granitoid intrusions, for example Unit 8 syenite and alkali-feldspar granite.

Alkali-feldspar granite, quartz syenite and syenite (Unit 8). Rocks assigned to this unit are concentrated south of the Churchill River but also occur as small bodies in the Dome Mountain area. Unit 8 south of the Churchill River is composed predominantly of buff to pink, medium grained, alkali-feldspar granite with lesser amounts of syenite and quartz syenite. As with all rocks of this unit, the granitoids are distinguished by a dark, gray-green color on broken surfaces. Mafic phases in these rocks consist of primary orthopyroxene and clinopyroxene that are severely altered to hornblende, biotite and opaque minerals. Structural state varies from massive to moderately foliated. The granite also contains numerous enclaves of amphibolite, ultramafite and metagabbroid, some of which appear to have been deformed prior to incorporation in Unit 8.

The small area of Unit 8 located 1.5 km north of the Churchill River comprises weakly deformed, buff, orthopyroxene-hornblende syenite. The crest of Dome

Mountain is formed by strongly foliated to lineated, buff to pink, alkali-feldspar pyroxene-hornblende granite, interspersed with amphibolite enclaves and intruded by aplite. Rusty pyroxene cores are locally recognizable within hornblende crystals, particularly in coarse grained or pegmatitic phases.

Contacts were not observed between Unit 8 and other units. However, the similarity between Unit 8 and the syenite and alkali-feldspar granite phases of Units 6 and 7 suggests a genetic and temporal link.

Miscellaneous small granitic intrusions (Unit 9). These intrusions occupy a number of small outcrop areas in the extensively drift-covered area west of the Cape Caribou River allochthon. Rock types are varied and include pink, fine to medium grained monzonite, quartz monzonite, granite and leucogranite. Structural state varies from weakly to moderately foliated. Contacts with the surrounding gneisses are unexposed but the strong contrast in deformation suggests that the granites postdate the development of the gneissic fabric in Unit 1.

Lower Brook metamorphic suite (Unit 10). This new term refers to a unit of pink foliated granitoids, associated gneisses and amphibolites exposed in the southwestern part of the map area. A small outcrop area around Muskrat Falls is also tentatively included within the unit.

The eastern part of the unit is dominated by pink to white weathering biotite (plus minor hornblende) granites, which vary from strongly foliated to weakly gneissic and migmatitic. To the west, these rocks become progressively gneissic with abundant development of migmatite textures, including lenticular granite leucosomes spotted with hornblende porphyroblasts. Gneissic texture is, however, very variably developed and outcrops of well banded gneiss occur interspersed with areas of less intensely deformed granite. The unit is characterized by an overall granitic composition and pink appearance, and comprises several granitic phases in addition to the ubiquitous pink biotite granites and gneiss. These phases include pale-pink to gray, granodiorite and quartz monzonite together with minor amounts of K-feldspar megacrystic granitoid. They typically occur interbanded on a centimetre to metre scale with pink granitic gneiss.

An important variant of Unit 10 is a subunit of chalky, pink weathering syenite and derived syenite gneiss (subunit 10sy) which underlies a north-trending belt in the centre of Unit 10. The syenites typically contain primary pyroxene that is locally identifiable as clinopyroxene, but in most cases, it is too severely altered to distinguish from orthopyroxene. The syenites and syenite gneisses are cut by concordant and discordant veins containing prominent porphyroblasts of green amphibole, commonly with rusty cores. The cores are thought to be orthopyroxene, however this has yet to be confirmed by petrography.

Amphibolites and metagabbroid enclaves are as common in Unit 10 as in other granitoid units in the area. Amphibolites are generally of hornblende + plagioclase ± garnet composition and are usually present as elongate rectilinear enclaves, which in small exposures are suggestive of mafic dikes. Where present in abundance, these impart a characteristic pink and black layered appearance to the unit. However, in larger outcrop areas such as Muskrat Falls, it is apparent that similar dike-like bodies bear a close spatial relationship to larger, more irregularly shaped pods of coarse grained amphibolite; the enclaves may have been derived from the large bodies by processes of magmatic spalling. Mafic enclaves with the syenite rocks of subunit 10sy locally have a resinous, dark-green to brown appearance and contain the granulite facies assemblage clinopyroxene + hornblende + plagioclase ± orthopyroxene ± garnet. Metagabbroid enclaves are relatively rare but locally preserve primary pyroxene and igneous layering.

Also present within Unit 10 are abundant screens of gray, migmatitic granitoid gneiss, which also contains numerous interbands of amphibolite and amphibolite gneiss. The gray granitoid gneisses are generally well banded with a pegmatitic granitic leucosome fraction that is spotted with hornblende porphyroblasts and minor amounts of rusty orthopyroxene. The most extensive area of gray gneiss is exposed along Lower Brook (Figure 3) where it alternates with bands of pink gneissic granite. Amphibolites within the gneisses locally contain clinopyroxene and orthopyroxene, and are generally similar in appearance to those preserved within the syenitic gneisses.

The origin of the gray gneiss screens is problematical. Larger enclaves, such as that exposed in Lower Brook, are similar in general appearance to gneisses of Unit 1, and might be interpreted as derived from that unit. However, cross-cutting relationships necessary to confirm this interpretation have not been found. Many of the smaller gray gneiss screens are interbanded with granitic gneisses on a scale of 0.5 to 2 m, and it is equivocal as to whether they represent earlier gneisses or highly metamorphosed granodiorite phases of Unit 10.

Plate 6: *Banded granitoid-amphibolite gneiss of subunit 1c intruded discordantly by foliated, nebulitic granite of Unit 10 (top); hammer is 34 cm long.*

Foliated to schlieric and nebulitic granites of Unit 10 intrude the gneiss of subunit 1c as concordant and discordant sheets (Plate 6). Relationships with other units are uncertain. The northern margin of Unit 10 is marked by a major south-dipping ductile shear zone, within which the granite gneisses and their amphibolite enclaves are converted to thinly layered, black and pink, mylonitic gneisses.

Minor intrusions. Amphibolite exposed in the Goose River between the two halves of Unit 7 monzonite is intruded by a fresh, posttectonic, 3 m wide diabase dike trending 018 . Granitoid rocks of Unit 6 in the vicinity of Dome Mountain are intruded by thin dikelets of fine grained, posttectonic granite for which a parent pluton has not been identified.

Tectonic Development

On the basis of structural trends (Figure 3), the area is divided into a northern domain dominated by northwest-trending fabrics, and a southern domain characterized by approximately west-trending fabrics. The two are separated by drift cover and the ductile shear zone forming the northern boundary of Unit 10.

Foliations in the northern domain are generally steep and are refolded about southeast-plunging second folds associated with a colinear mineral lineation. The annular outcrop pattern of the belt of Unit 2, immediately north of the Goose River, is suggestive of an interference pattern produced by large scale refolding of an early structure about southeast-plunging second fold axes; a pattern which is consistent with the geometry of the minor second fold structures. The pattern could also be interpreted as a sheath fold, however, minor sheath or 'eye' folds have not been seen in association with the structure.

Mapping to the north of the map area by Ryan *et al.* (1982) revealed that the northwestern margin of the Cape Caribou River allochthon is bounded by a major, mylonitic, ductile shear zone with a shallow, southeasterly dip (Figure 2). On Figure 3 this zone is inferred to extend into the map area as a lateral thrust ramp. However, of the few scattered outcrops seen in this area, none show evidence of pervasive mylonitization. Therefore, it is evident that any southerly extension of the thrust must be a very narrow zone that is obscured by drift.

Foliations in the northern domain become re-oriented into east-west trends near the ductile shear zone that marks the northern boundary of Unit 10. The shallow, southerly dip and strong, southeast-plunging lineation of this structure are taken to indicate that it is a zone of northwest-directed thrust movement. Several pronounced topographic linears in the south, some of them associated with mylonite, are interpreted to mark the site of subsidiary thrusts.

Foliations in the southern domain are largely of east-west trend and moderate to shallow, southerly dip. Lineations and associated minor fold axes plunge moderately to the southeast and are colinear with those in the northern domain. It is evident, therefore, that although trends of foliation and ductile shear zones vary considerably throughout the map area, the direction of tectonic transport, as deduced from second-phase structures, was consistently to the northwest.

The intensity of deformation and metamorphism, as signified by the development of gneissic and migmatitic textures, increases from east to west within the map area. Rocks of the North West River anorthositic intrusive suite within the Cape Caribou River allochthon become strongly foliated to the west, but never gneissic or migmatitic, a state which contrasts sharply with the banded, migmatitic texture of Unit 1 at the base of the allochthon. Ryan *et al.* (1982) have discussed evidence suggesting that gabbroic rocks discordantly intrude granitoid gneisses near the base of the allochthon on its northwest margin. However, field evidence to corroborate this interpretation is lacking from the present map area.

A problem is also posed by the relationship depicted in Plate 3 wherein a xenolith of foliated or lineated amphibolite (Unit 3) is incorporated in zonally deformed monzonite of Unit 7. The implication of this relationship is that the metagabbroid component (Unit 3) of the North West River anorthosite intrusive suite underwent an early period of deformation prior to monzonite intrusion. However, this relationship has only been observed at one locality and its regional significance is, as yet, unclear.

The Dome Mountain intrusive suite shows a progradation from largely massive textures in the east to strongly foliated, locally gneissic and migmatitic textures in the west, a trend that is continued within the rocks of the Lower Brook metamorphic suite, which also become progressively gneissic to the west. There is at present no evidence for a metamorphic hiatus between the Dome Mountain and Lower Brook suites. However, the Lower Brook suite granites discordantly intrude the gneisses of subunit 1c, and it must be concluded that at least in this southern part of the map area, there is evidence for two periods of high-grade metamorphism, both associated with migmatization. The Lower Brook metamorphic suite also preserves relicts of a granulite facies metamorphism in enclaves of possibly earlier rocks; however, the bulk of the suite appears to have been affected only by amphibolite facies metamorphism, although this has yet to be confirmed in all areas.

In summary, there is limited field evidence suggesting that formation of at least part of the Unit 1 gray gneiss terrane predated intrusion of the major plutonic suites of the area. However, it is probably an oversimplification to regard all parts of Unit 1 as being necessarily of the same age, or as having formed during the same period of metamorphic development. The unit shows considerable internal variation in metamorphic state and it is quite possible that some of its more massive parts (such as subunit 1qd - Susan River quartz diorite) could be equivalent in age to rocks in the North West River, Dome Mountain and Lower Brook suites.

Postorogenic tectonism is represented by development of the Lake Melville graben, of suspected late Precambrian-early Paleozoic age. Details regarding interpretation and development of the structure are given in Gower *et al. (in press)*. The northern boundary fault of the structure is inferred to lie along the base of the linear escarpment marking the southeastern edge of the anorthosite. Some of the brittle crushing and shearing that occur in outcrops along the escarpment may be attributable to graben faulting, however, no systematic fracture pattern of northeasterly trend was noted.

The western boundary fault of the graben is inferred entirely on the basis of aeromagnetic evidence (GSC, 1970). The linear positive anomaly which extends southeastward from Unit 3 metagabbroids (Figure 3) has a very steep gradient on its northeastern side, inferred to be the site of the fault.

The aeromagnetic map also shows the southeastern side of the graben to be underlain by a broad positive anomaly, which slopes gradually north into a deep low along the northwestern side of the graben. It is speculated that the magnetic high represents a northward extension of monzonites of the Mealy Mountains intrusive suite (Emslie, 1976), which are generally characterized by a positive magnetic expression (GSC, 1971), and that the magnetic low may either represent foundered anorthosite, or more tentatively, late Precambrian red beds of the Double Mer Formation, which forms the graben fill in areas to the northeast (Kindle, 1924; Erdmer, 1984; Gower *et al.*, *in press).*

MINERALIZATION

The area formed part of the BRINEX Labrador concessions and was prospected during the 1950's and 1960's. It was later included in a reconnaissance airborne-spectrometer program by Hudbay Uranium Ltd. (Fenton, 1977), and also included in the National Geochemical Reconnaissance Program (GSC, 1977).

Minor amounts of ilmenite are found in association with magnetite in the anorthosite of Unit 4. Magnetite forms pronounced concentrations, both as an intercumulus phase and as veins, in a zone of anorthosite near the basal contact between Unit 4 and Unit 3. This zone underlies the crest of the pronounced, positive, aeromagnetic anomaly that follows the contact of the anorthosite and Unit 3 metagabbroids, suggesting that the area may contain larger concentrations of mineralization. Small concentrations of ilmenite were also found within pegmatitic phases in Unit 2 metasedimentary gneiss.

Douglas (1976) reported a small quartz-vein occurrence of chalcopyrite on the west side of Dome Mountain; however this showing was not found during our work.

The anorthosite of Unit 4, although displaying local labradorescence, is generally strongly fractured and partially recrystallized, thus severely limiting its potential as gem or dimension stone.

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THE ATIKONAK RIVER MASSIF AND SURROUNDING AREA, WESTERN LABRADOR AND QUÉBEC

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ABSTRACT

The Atikonak River massif is a suite of troctolitic, noritic and anorthositic rocks in southwestern Labrador. Spatially related pyroxene quartz monzonite and rapakivi-textured quartz syenite to granite occur with the anorthositic rocks in an association that is common to anorthositic suites elsewhere in Labrador. Areas of paragneiss and K-feldspar porphyritic granite also occur in and around the massif.

Magmatic structures and textures are well preserved in the Atikonak River massif and clearly demonstrate that intrusion of the basic magmas was not accomplished as highly crystalline mushes. Widespread development of mineralogical layering, including graded and cross-bedded varieties, attests to the presence of substantial amounts of liquid at the time of intrusion. Evidence of sub-solidus reaction between olivine and plagioclase is common in crystal cumulates in the massif. At present it is unclear to what extent such reactions took place during cooling of the massif from magmatic temperatures, or are the result of later regional metamorphism.

The massif is rimmed on the northwest side by monzonitic and rapakivi-textured rocks, which are in turn adjacent to paragneiss that is intruded by gabbronoritic and granitoid plutonic rocks. On the southeast side, the anorthositic rocks thermally affect part of a gabbronorite body. In the southeast of the map area, the anorthositic rocks and the amphibolite equivalents of the gabbronorite are intruded by a suite of predominantly equigranular or K-feldspar megacrystic granitoid rocks.

INTRODUCTION

The 1985 mapping program consisted of a joint project by the Geological Survey of Canada and the Newfoundland Department of Mines and Energy. The provincial group continued the regional mapping that was started in 1982 under a series of co-operative programs between the two government bodies. The 1985 field season was the first for this project under the present Canada-Newfoundland Mineral Development Agreement, 1984-1989, aimed at completing the regional mapping of southwestern Labrador. A Geological Survey of Canada team joined the program to assist in the mapping, and as a part of the ongoing study of the anorthositic bodies of eastern Canada.

The map area is equidistant (about 200 km) from Churchill Falls, Labrador City and Sept Îles (Figure 1), and includes approximately 5,900 km^2 of the southern tip of western Labrador. It encompasses NTS map areas 23A/1,2,7 and 8, 22P/15, most of 22P/16 and those parts of 22P/9 and 10 that lie north of the Gulf of St. Lawrence-Atlantic Ocean watershed; mapping was at 1:100,000 scale. The parts of the map area that fell within Québec were given a comparatively cursory examination, with the exception of a few traverses designed to aid in the geological interpretation of the Labrador side of the border.

Exposure throughout most of the upland-dominated, western and southern region is excellent, and in contrast to that in the predominantly lowlying, drift-covered areas in the northern and eastern parts of the map area. Access during this study was by float plane and helicopter.

The first geological description from the map area is given by Low (1896) who studied the area around the southeast corner of Atikonak Lake and the Romaine River in August of 1894.

No further work was done in the area until the 1950's, when BRINEX conducted an exploration program that included geological reconnaissance in 1953 and airborne

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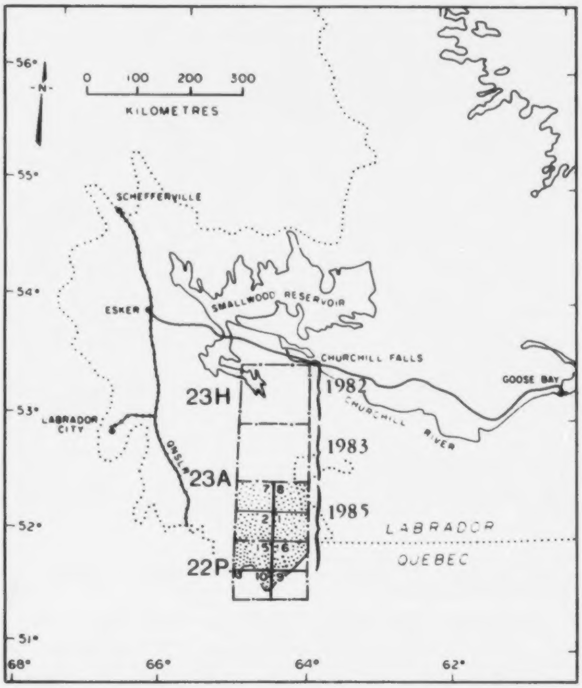

Figure 1: *Location map of the Atikonak River massif, southwestern Labrador.*

geophysics in 1954. Ground prospecting and follow-up work on several anomalies were done in 1956 and the whole program was summarized by Pyke (1956). The anomalies are underlain by anorthositic rocks and numerous, but minor, occurrences of Fe, Ti and Cu mineralization were found throughout the area.

Blais (1960) described similar rocks to those of the Atikonak River massif from the Waco area, 80 km to the southwest, which he called the Waco igneous complex. These rocks lie at the southwestern end of the Lac Fournier massif, which was described by Sharma and Franconi (1975). Earlier reconnaissance mapping of parts of the map area resulted in 1:250,000 scale maps by Stevenson (1968) of 23A and Sharma and Franconi (1975) of the Québec portion of 22P. These maps were incorporated into broader compilations at 1:1,000,000 scale by Greene (1972) and 1:1,500,000 scale by Avramtchev and Marcoux (1980).

The upland core of the map area is underlain mostly by the anorthosite-related suite and its associated granitoid rocks. Anorthositic massifs and their associated intrusions constitute major components of the northeastern Grenville Province (Emslie, 1985). The anorthositic rocks described here are collectively termed the Atikonak River massif, and are a northeasterly extension of the Lac Fournier massif of Sharma and Franconi (1975). The present mapping has shown that, in addition to forming a generally distinctive physiographic feature, the Atikonak River massif is almost completely isolated from similar rocks to the south by older paragneiss and younger granitic intrusions (Figure 3). The aeromagnetic map (Geological Survey of Canada, 1985) indicates that the exposure gap between the Atikonak River massif and the Lac Fournier massif may be underlain by paragneiss rather than anorthositic rocks (as shown on Figure 3) although structural data (Figure 3) suggest that the two massifs are continuous beneath the paragneiss. For these reasons, and to add precision to subsequent description, the new name is introduced in this publication and in a companion report by Emslie *et al.* (1986). Some of the description of the anorthositic rocks is taken directly from the latter report.

GENERAL GEOLOGY

Regional Setting

The map area lies within the Grenville Province between 175 km and 275 km south of the Grenville Front[1] (Figure 2). The bulk of the region to the north, between the Grenville Front and the map area, is composed of high-grade gneisses and temporally related plutonic rocks that are remnants of the late Early Proterozoic Labrador orogen (Thomas *et al.*, *in press*). These rocks were stacked into a parautochthon and a number of overlying allochthons during the Grenvillian orogeny (Rivers and Nunn, 1985) and are assigned, here, to an 'external' zone of the Grenville orogen (Figure 2). The allochthons are part of a chain of structures that form a more or less continuous zone along the strike length of the eastern Grenville Province (Wardle *et al.*, *in press;* Rivers and Chown, *in press*). Near the northern margin of the map area, the Grenvillian metamorphic grade is in upper amphibolite to granulite facies, however, the degree of Grenvillian reworking in the allochthonous terranes is still very uncertain.

The present area lies within an 'interior' zone of the Grenville orogen that stretches south to the Gulf of St. Lawrence (Figure 2), and consists of high-grade gneisses of unknown but pre-Grenvillian age (Wynne-Edwards, 1972; Bourne *et al.*, 1977; Loveridge, 1986), including abundant plutonic rocks. The tectonic and orogenic make-up of this area is poorly understood, but large volumes of massif-type anorthosites are characteristic, represented by the Atikonak River massif within the map area.

Supracrustal Gneisses (Unit 1)

The supracrustal gneisses comprise pelitic to semipelitic paragneiss and minor, thin layers of psammitic paragneiss and basic gneiss. The largest area of paragneiss occurs in the northwestern part of the map area (Figure 3) where it generally consists of a fine to medium grained migmatite that contains centimetre-scale, pink to buff, granitic layers and millimetre-scale, aluminous restite seams and schlieren (Plate 1). The respective mineralogies of the leucosomes and melanosomes consist of a feldspar + quartz ± biotite ± opaque oxide assemblage, and a sillimanite + opaque oxide ± biotite ± garnet ± quartz or plagioclase assemblage (subunit 1a). Biotite is commonly absent or minor in both

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[1] Approximate northern limit of Grenvillian ductile deformation in supracrustal cover sequences (Rivers and Nunn, 1985).

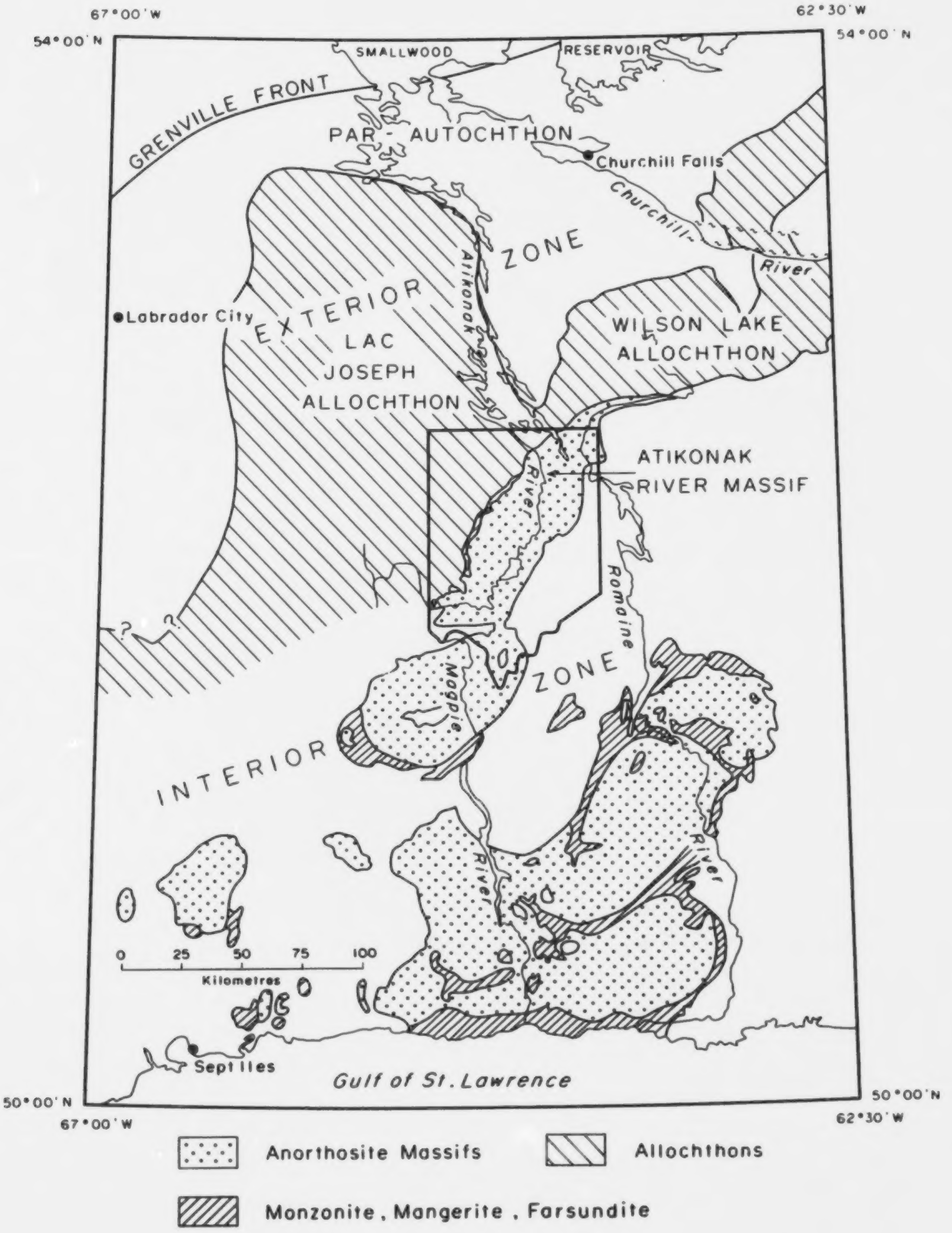

67°00'W
62°30'W
54°00'N
54°00'N
SMALLWOOD
RESERVOIR
GRENVILLE FRONT
PAR - AUTOCHTHON
Churchill Falls
Churchill
River
ZONE
Atikonak
EXTERIOR
Labrador City
LAC
JOSEPH
ALLOCHTHON
WILSON LAKE
ALLOCHTHON
ATIKONAK
RIVER MASSIF
River
Romaine
ZONE
Magpie
INTERIOR
River
River
0
25
50
75
100
Kilometres
Sept Iles
Gulf of St. Lawrence
50°00'N
50°00'N
67°00'W
62°30'W
Anorthosite Massifs
Allochthons
Monzonite, Mangerite, Farsundite

Figure 2: *Regional setting of the map area, within a section across the Grenville Province from the Grenville Front to the Gulf of St. Lawrence. Figure 3 area is indicated.*

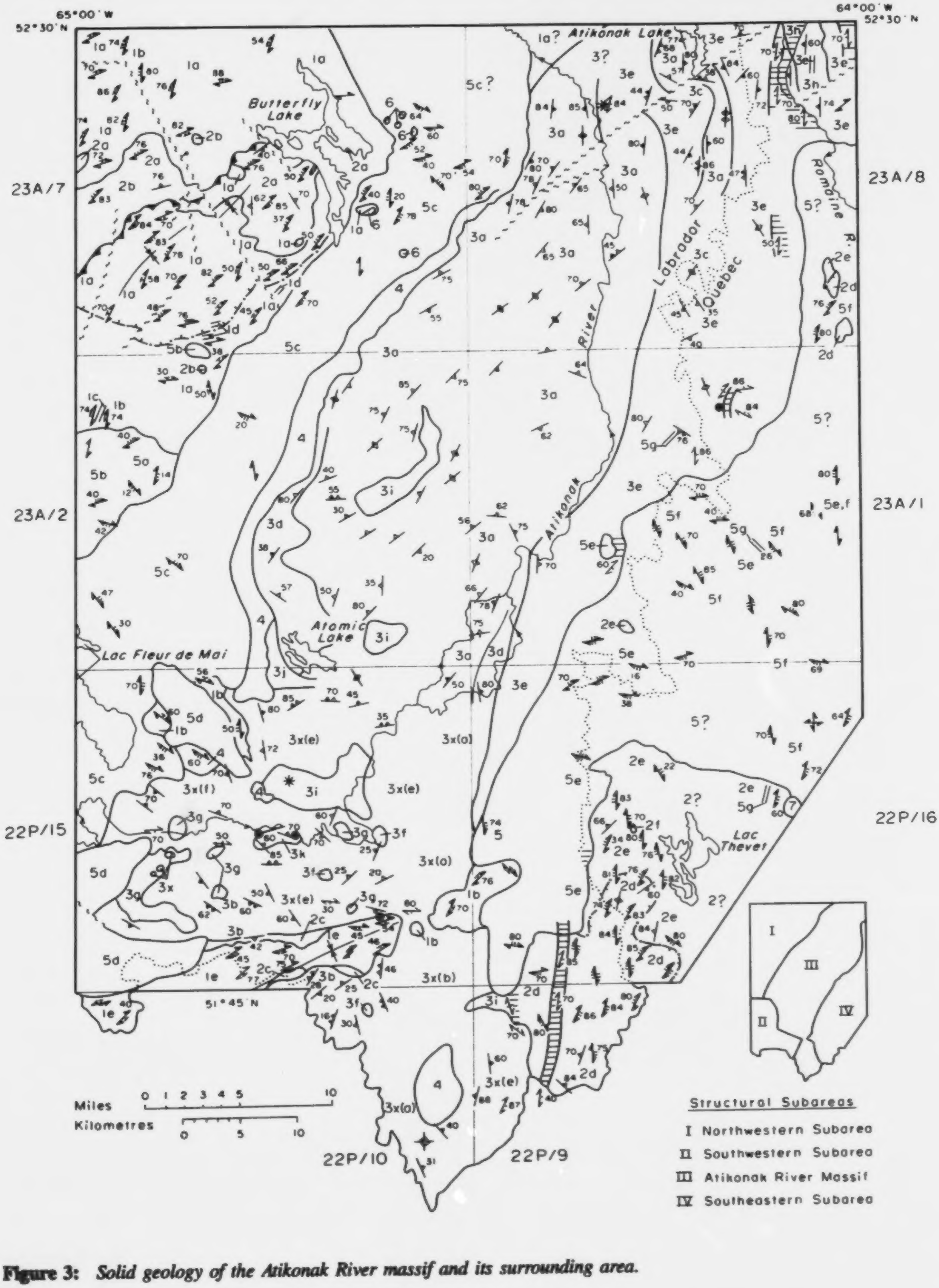

65°00'W
52°30'N
64°00'W
52°30'N
51°45'N
23A/7
23A/8
23A/2
23A/1
22P/15
22P/16
22P/10
22P/9
Atikonak Lake
Butterfly Lake
Atomic Lake
Lac Fleur de Mai
Lac Thevet
Atikonak River
Romaine R.
Labrador
Quebec
Miles
0 1 2 3 4 5 10
Kilometres
0 5 10
I
II
III
IV
Structural Subareas
I Northwestern Subarea
II Southwestern Subarea
III Atikonak River Massif
IV Southeastern Subarea

Figure 3: *Solid geology of the Atikonak River massif and its surrounding area.*

LEGEND

HELIKIAN or younger

7 Quartz feldspar porphyry.

HELIKIAN (no chronological order implied)

6 Gabbro.

5 **Granitoid plutonic suites.** 5a, seriate to equigranular, fine to coarse grained granite; 5b, K-feldspar megacrystic quartz monzonite; 5c, rapakivi-textured granite to quartz syenite; 5d, K-feldspar porphyritic,blue-quartz granite; 5e, equigranular, fine to coarse grained granite; 5f, K-feldspar megacrystic granite, quartz syenite and quartz monzonite; 5g, gray, granitic gneiss dikes.

4 Pyroxene monzonite (mangerite) and pyroxene quartz monzonite (farsundite).

3 **Atikonak River massif:** coarse to very coarse grained, mostly igneous and/or corona textured.

Troctolite association: 3a and 3b, layered and laminated troctolite, leucotroctolite and anorthosite.

Transition group: 3c, layered and laminated troctolite, hypersthene troctolite, leucotroctolite and anorthosite with layered and laminated or intergranular-textured norite and leuconorite.

Noritic association: 3d, layered and laminated norite, leuconorite and anorthosite; 3e, layered and intergranular-textured norite and leuconorite with layered (rarely laminated) anorthosite; 3f, seriate, medium to coarse grained, intergranular-textured norite and leuconorite; 3g, homogeneous, very coarse grained, intergranular-textured norite.

Anorthosite groups: 3h, layered and laminated anorthosite, magnetite anorthosite and hypersthene-magnetite anorthosite; 3i, isotropic anorthosite.

Small layered intrusions: 3j, Beaver Pond gabbro - medium grained olivine gabbro, troctolite and gabbro; 3k, medium grained ferrodiorite.

Uncertain association: 3x, structural and textural equivalents of the rest of the Atikonak River massif; complete replacement of ferromagnesian mineralogy by hydrous assemblages.

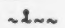
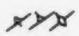
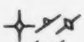
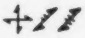
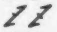
PALEOHELIKIAN and HELIKIAN

2 **Basic plutonic suites:** medium grained, mostly metamorphic textured. 2a, leuconorite, leucogabbronorite and quartz leuconorite; 2b, gabbro and leucogabbro; 2c, leuconorite and gabbronorite with minor biotite norite and magnetite anorthosite; 2d, leucogabbronorite; 2e, amphibolite and minor ultramafic amphibolite; 2f, serpentinized ultramafic rock.

PALEOHELIKIAN or older

1 **Supracrustal gneisses.** 1a, sillimanite-bearing, biotite-poor, granite-layered, pelitic to semipelitic paragneiss; 1b, more biotite-rich equivalent of 1a; 1c, psammitic paragneiss; 1d, basic gneiss; 1e, 1a-type paragneiss interlayered with sillimanite-free gneiss, commonly cordierite bearing.

SYMBOLS

Geological boundary (inferred)	
Fault, tick on downthrown side (inferred)	
Thrust, teeth in dip direction (uncertain)	
Bedding, tops unknown (inclined)	
Igneous layering, tops known (overturned, inclined, vertical)	
Igneous layering, tops unknown (subhorizontal, inclined, vertical)	
Igneous lamination (inclined, vertical)	
Igneous layering and lamination parallel (overturned, inclined, vertical)	
Gneissic layering (inclined, vertical)	
Mineral foliation (subhorizontal, inclined, vertical)	
Foliation and gneissic layering parallel (inclined, vertical)	
Foliation in shear zones (inclined, vertical)	
Subunit layers (1c, 1d, 5g)	
Amphibolite-granulite facies boundary, tick on higher-grade side (approximate)	
Shear zone	
Synform (inferred)	
Provincial boundary	
Main mineral occurrences: labradorite	✱
magnetite	●

the leucosome and the restite, but may also form discontinuous selvages between the two. Locally, in the northwest part of the map area and in gneiss pendants within the plutonic rocks elsewhere in the map area, the restite is characterized by a medium to coarse grained sillimanite + biotite + magnetite ± garnet assemblage (subunit 1b).

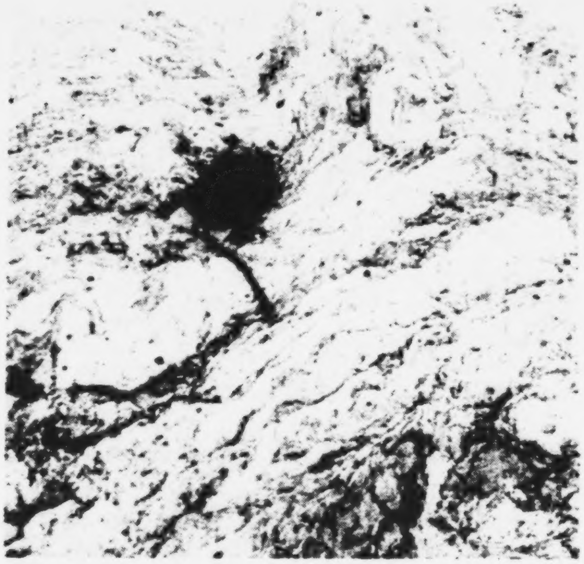


Plate 1: *Strongly differentiated stromatic paragneiss; alternating layers of granite and sillimanite- and magnetite-rich restite (subunit 1a). The layering is both isoclinally and openly folded and a steeply pitching lineation associated with the tighter folds is evident. The clinometer is 10 cm long. M&E-GN85-CS8-32.*

The migmatitic paragneiss (subunits 1a and 1b) varies from a rock that has a well defined layering (Plate 1) to one in which the restite forms a discontinuous location fabric (Turner and Weiss, 1963, pages 34-35) within the granitic leucosome. In places, the leucosome has coalesced to form a nebulitic rock or an inhomogeneous diatexite containing randomly scattered remnants of restite. All gradations occur between this and the stromatic migmatite. Later generations of migmatitic material are usually pink, coarse grained, discordant granite veins, but include fine to medium grained aplite or microgranite dikes and veins, and sheets of granodiorite. The discordant veins are commonly quartz rich (ranging to quartzolite), particularly in the northwestern parts of the map area.

Centimetre- to metre-scale layers of psammitic paragneiss occur within the pelitic and semipelitic paragneiss, either as homogeneous, quartzofeldspathic layers or as a finely layered (bedded ?), quartzofeldspathic gneiss containing very thin pelitic laminae. Discordant migmatite is less abundant in the psammitic layers and commonly is very quartz rich. In the west of NTS map area A/2, thinly bedded, quartzose psammites containing thin biotite- and muscovite-rich pelitic laminae occur in a layer 60 m or more thick (subunit 1c).

Metabasic rocks are intercalated with the paragneiss sequence. Most commonly they form thin layers, strips, enclaves and boudin trains of green to brown weathering, plagioclase + clinopyroxene ± orthopyroxene metabasite. Several 5 to 50 m thick layers of black, massive to modally layered amphibolite or pyroxene-bearing metabasite are also present (subunit 1d). A quartz vein segregation fabric is commonly developed, and at one locality the amphibolites display a discontinuous, pale-green, color banding. These metabasic rocks are thought to be derived from extrusive or hypabyssal protoliths within the supracrustal succession.

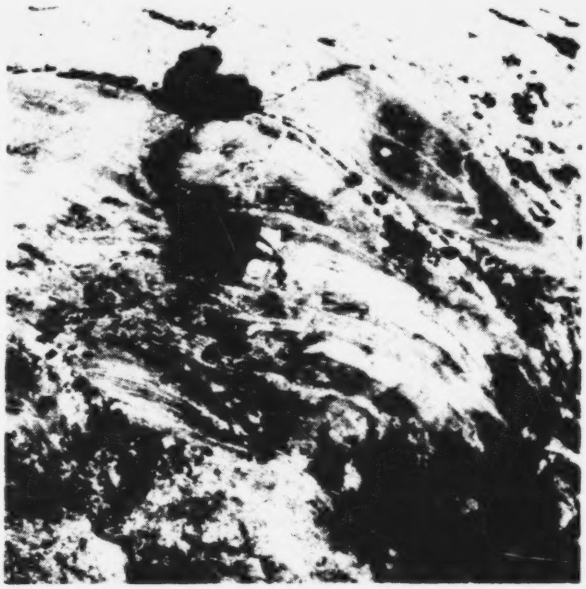


Plate 2: *Compositionally and leucosome-layered metabasic inclusions, veined and enclosed in an orthopyroxene-bearing neosome (subunit 1d). The clinometer is 10 cm long. M&E-GN85-CS1-32.*

Thin layers of metabasic rock are commonly net veined or sheeted by granodioritic to tonalitic neosomes (Plate 2). In extreme cases, the neosome occurs as centimetre- to metre-scale sheets, which are interlayered with the paragneiss, and contains only scattered metabasite enclaves. The neosomes consist of feldspar + quartz + biotite ± garnet or feldspar + quartz + orthopyroxene ± biotite assemblages.

In the southwestern part of the map area, the paragneiss (subunit 1e) consists mostly of typical pelitic to semipelitic migmatite, similar to subunit 1a, which, in areas that are generally close to the contact with Unit 3, contains cordierite as well as sillimanite. This paragneiss is intercalated , on a scale of tens of metres, with sillimanite-free layers in which the restite appears to consist of magnetite and minor biotite and quartz. The sillimanite-free migmatite is either structurally similar to the normal, stromatic paragneiss or is broken up into zones of agmatite in which the layered and folded paragneiss is isolated as numerous, small, close-spaced blocks in a later generation of migmatite. Minor layers of psammitic to semipelitic composition in the paragneiss contain less developed location fabrics than the rest of the sequence, and the restite commonly consists only of cordierite ± magnetite. Many of the rocks are orthopyroxene bearing and are more distinctly brown weathering than the paragneisses in the rest of the map area. Cordierite is dark gray to black, or bluish, and commonly has a vitreous lustre.

The southwestern area of paragneiss contains thin layers of metabasite and discordant, metre-scale sheets of granitic migmatite. It structurally overlies the anorthositic rocks and may be a large roof pendant.

The paragneiss contains dimensionally oriented fabrics and/or polygonal recrystallization textures. The generally lineated, dynamic, restite mineralogy comprises sillimanite, opaques and biotite. In hand specimen, garnet appears to be posttectonic and may be associated with a largely mimetic crystallization of biotite selvages and scattered, coarse grained, sillimanite needles, up to 13 mm by 1 mm in size. The quartzofeldspathic layers are commonly polygonally recrystallized, but may also contain dynamic textural elements, either in the form of a mineral fabric or as shape aggregates.

Basic Plutonic Suites (Unit 2)

The unit consists of two suites that occur on each side of the Atikonak River massif, and a third area of metabasic rock flanking the paragneiss in the southwest part of the map area.

To the northwest is a suite (subunits 2a and 2b) of green and black gabbro (color index, 35-65) and gray leuconorite (Plate 3), leucogabbronorite and quartz leuconorite (color index, 10-35). These rock types are medium grained, massive, and range in texture from relict igneous to strongly lineated. Rarely, the gabbroic rocks (subunit 2b) and the noritic rocks (subunit 2a) are layered. The gabbro contains clots of clinopyroxene that occur in knobbly weathering layers. The noritic rocks contain layers that have a range of textural, grain size and compositional variations, including fine grained, equigranular leuconorite, orthopyroxene porphyroblastic melanorite, and a websteritic rock, as well as layers of the more common rock types. The layering generally occurs on a metre scale. The noritic rocks commonly contain scattered to abundant, generally finer grained, cognate xenoliths, some of which may be disrupted dikes.

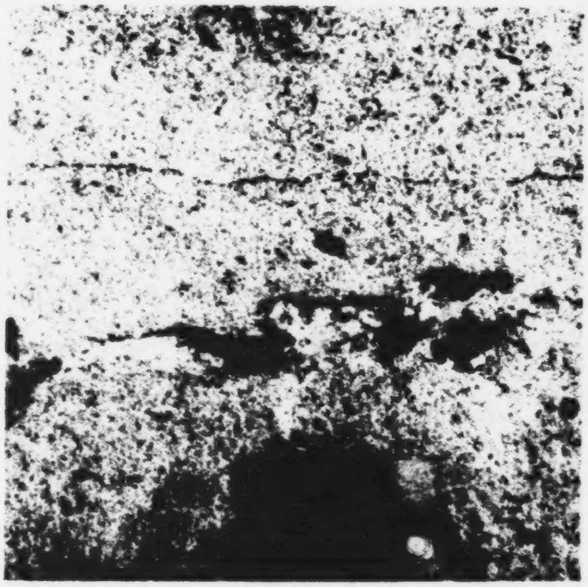


Plate 3: *Medium grained, equigranular leuconorite with a biotite- and orthopyroxene-bearing metamorphic segregation (subunit 2a). The clinometer is 10 cm long. M&E-GN85-CS2-35.*

Relict igneous mineralogy is found in rare pegmatitic patches in gabbro, in a microgabbro, and in coarse grained anorthosite veins that cut a leucogabbronorite. The microgabbro may be olivine bearing and has an intergranular texture. It appears to grade into a medium grained, plagioclase-biotite metamorphic rock. The remaining mineralogies are metamorphic and generally form a plagioclase + pyroxene + biotite ± quartz assemblage that has a weak, linear, mineral fabric. The rocks commonly contain coarse grained, metamorphic segregations of similar composition to the host (Plate 3), locally containing quartz. Rarely, the leucogabbronorite contains a few, scattered K-feldspar porphyroblasts.

Granitoid veins cut the suite and range from alkali-feldspar granite to tonalite in composition, and include rare, layered, muscovite granite pegmatite. Veins at the granitic end of the spectrum locally contain tourmaline; those of granodioritic to tonalitic composition commonly contain orthopyroxene and, more rarely, garnet. Textures in the veins range from igneous to metamorphic. Parts of the veins, particularly the margins, are commonly strongly rodded and locally appear much more deformed than their metabasic host. The quartz leuconorite is more intensely foliated than the quartz-free noritic rocks, and flattening of the usually random or net-veined nature of the granite veins has produced a layered rock in places.

The presence of the quartz-bearing rock types suggests that the noritic part of the suite may represent a diorite - quartz diorite protolith.

The northwestern basic plutonic suite intrudes, and encloses xenoliths of, the supracrustal basic gneiss (subunit 1d), and is presumed also to intrude the paragneiss sequence since these gneisses are normally interlayered.

Metabasic rocks (subunit 2c) flank parts of the paragneiss in the southwestern pendant. They consist of fine to medium grained, equigranular leuconorite containing layers of gabbronorite and biotite norite. A distinctive layer of cumulate-textured magnetite anorthosite, containing centimetre-scale, oval augen of polygonal plagioclase in a discontinuous groundmass of magnetite, occurs in the metabasite sequence on the north side of the pendant. The metabasic rocks are concordant with the paragneiss in the pendant and are cut by leuconorite dikes of Unit 3.

The southeastern basic plutonic suite comprises a light-colored, dark-spotted leucogabbronorite (subunit 2d) and black amphibolites (subunit 2e), together with some minor rock types. The leucogabbronorite is fine to medium grained, equigranular, and contains a largely dynamic, metamorphic mineralogy, although relict igneous textures are preserved normal to the lineation in areas of low strain. Rare compositional variations in the leucogabbronorite consist of diffuse layers of slightly different color index (Plate 4) and more obvious layers of gabbronorite. Plagioclase-bearing pyroxenite layers seem to parallel these variations, and may be igneous layering or dikes. Dikes of mafic to ultramafic amphibolite cut the layering (Plate 4), and hairline fractures containing either felsic or mafic minerals are also present. These features are best preserved in the low-strain areas where they are folded and at high angles to the foliation; throughout most of the leucogabbronorite they are attenuated and subparallel to the foliation. In the southwest of its outcrop area, the leucogabbronorite is a dark gray, compact, equigranular rock and is thought to be a hornfels adjacent to the anorthosite.

Plate 4: *Diffusely layered and foliated leucogabbronorite with a crosscutting dike of foliated amphibolite (subunit 2d). The amphibolite contains an oriented shape fabric of polygonal plagioclase after plagioclase phenocrysts. The clinometer is 10 cm long. M&E-GN85-CS5-30.*

The amphibolite (subunit 2e) is a medium grained, foliated rock with a predominantly LS mineral fabric of hornblende and plagioclase (Plate 5). Rare compositional variations may represent relict dikes or layering (compare Plates 4 and 5). Finer grained, gray, more strongly foliated zones also occur. Locally, subunit 2e consists of plagioclase-biotite rocks and appears to grade into granitoid-layered, tonalitic gneisses. Outcrops of ultramafic and mafic amphibolite, and appinite dikes are rare rock types in the amphibolite assemblage. Two kilometres northwest of Lac Thevet, the amphibolite contains an area of approximately 250 by 150 m of serpentinized ultramafic rock containing clinopyroxene-rich patches and discontinuous layers (subunit 2f).

Plate 5: *Veined (white area above pencil) and foliated amphibolite (subunit 2e) containing an earlier compositional layering (compare with Plate 4). The pencil is 10.5 cm long. M&E-GN85-CS6-10.*

Subunits 2d and 2e underlie predominantly upland and lowland areas respectively. However, the relationship is not a simple spatial one, i.e., areas of gabbronorite occur within the amphibolite and amphibolite locally underlies the upland periphery.

Throughout its outcrop area the amphibolite is cut by dikes and net vein systems related to Unit 5.

The Atikonak River Massif (Unit 3)

Major rock types of the Atikonak River massif include leucotroctolite (color index, 10-25), troctolite (color index, 25-50), leuconorite (color index, 10-25), norite (color index, 25-50), and anorthosite (color index, <10). A preliminary division of the massif is made on the basis of ferromagnesian mineralogy, resulting in troctolitic and noritic associations. Within these associations further subdivision is attempted using composition, structure and texture, although relationships between and within each association are commonly very complex. Subsequent alteration of the primary ferromagnesian mineralogy makes division impossible in some areas. Large masses of true anorthosite are distinctly subordinate parts of the massif. Substantial parts of all subunits are essentially massive with little variation in mineral proportions or grain sizes.

Troctolite and leucotroctolite (subunit 3a), typically with more plagioclase-rich interlayers that include anorthosite (Plate 6), form dominant rock types in the better exposed

Plate 6: *Leucotroctolites (subunit 3a); layered section dipping westerly at a moderate angle in outcrops along the Atikonak River. GSC-203423-L.*

upland area north and west of the Atikonak River. These occur with separate leuconorite and norite layers and areas (subunit 3d) that also contain anorthosite interlayers. Both subunits exhibit a considerable variety of structures and textures; they are broadly characterized by modal layering (Plates 6 and 12) and variably developed igneous lamination (Plate 13), but massive and isotropic layers occur, particularly in subunit 3d to the north of Atomic Lake. Mineral layering several centimetres to several metres wide is widespread, and is displayed particularly well in burned-over areas and along larger rivers (Plate 6). Plagioclase is usually dark gray to black and the rocks are dark gray on both fresh and weathered surfaces. The feldspar forms mostly tabular crystals 1 to 5 cm across, but layers of considerably greater grain size are common. The grain size of individual mineral species is usually homogeneous throughout a layer but grain-size grading also occurs. Orthopyroxene is commonly a subordinate or minor constituent of the troctolitic association. Within any one layer, the ferromagnesian minerals are usually evenly distributed, however, mineral grading and more rarely cross-bedding and slump features are present in subunit 3a.

To the east of the uplands, topographically lower areas are underlain largely by rocks of noritic association (subunits 3e and 3h). A layer of troctolitic association rocks (subunit 3a), 1 to 4 km wide, occurs along a strike length of 18 km within the noritic rocks, about 6 km east of the main contact between subunits 3a and 3e. Locally, a transitional group (subunit 3c) occurs between this layer and subunit 3e. The transitional group consists of decimetre- to metre-scale interlayering of laminated troctolite and leucotroctolite, with anorthosite, leuconorite and norite that are either laminated or have an intergranular texture. Some layers contain both olivine and orthopyroxene.

The noritic association in the eastern part of the map area consists of layered norite, leuconorite and anorthosite (subunit 3e). Layering occurs on decimetre- to metre-scales but is commonly indistinct within an outcrop; rather, compositions vary between groups of outcrops, and in the better exposed northern parts of this subunit appear to relate to layering on a kilometre scale. Mineral grading is present in some of the more finely layered parts of the sequence. Anorthosite layers are locally laminated, but in contrast to subunit 3d, the orthopyroxene-bearing layers nearly everywhere have an intergranular texture and are very coarse grained (Plate 7). Plagioclase is commonly irridescent in subunit 3e and opaque oxide pods, clots and layers are most common in this subunit.

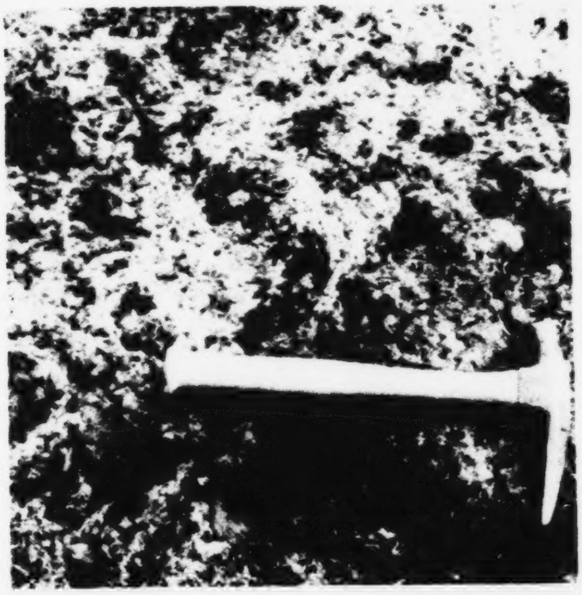


Plate 7: *Leuconorite (subunit 3e); randomly oriented, partly recrystallized plagioclase laths with intergranular orthopyroxene and scattered patches of coarser grained orthopyroxene. The hammer is 33 cm long. M&E-GN85-CS6-16.*

A 3 to 4 km thick, laminated anorthosite (subunit 3h) is intercalated with subunit 3e in the northeastern corner of the map area. The anorthosite is characterized by red-brown, 1 to 4 cm long plagioclase and sporadic, decimetre-scale, oval patches of intercumulus magnetite and minor orthopyroxene.

Alteration of the ferromagnesian minerals and corona development are abundant throughout the northern map sheets (NTS area 23A), particularly in the lower-lying northern and eastern parts. It is generally possible to differentiate between troctolitic and noritic association rocks using relict mineralogy, unaltered cores, differing types of coronas and pseudomorphs, and texture. In the south, however, these features are commonly not distinct enough, and large areas of unknown or uncertain affinity (subunit 3x) are indicated together with their possible protoliths (in parentheses on Figure 3).

Troctolitic association rocks are either similar to subunit 3a or form subunit 3b in the south of the map area (NTS map area 22P). Subunit 3b comprises anorthosite containing patches of troctolite or leucotroctolite, 5 to 20 cm across (giving this rock an overall leucotroctolite composition), and intercalated layers of anorthosite. Rarely, the patches coalesce to form a more or less continuous layering (Plate 8), and clinopyroxene occurs with olivine in one locality. Modal layering of anorthosite and leucotroctolite, containing varying concentrations of olivine-bearing patches, and plagioclase lamination are common; anorthosite generally forms the thicker layers.

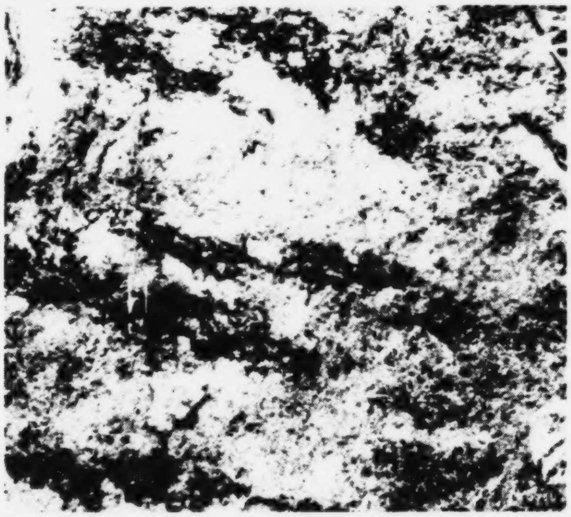


Plate 8: *Anorthosite containing isolated and coalesced patches of troctolite defining a discontinuous layering (subunit 3b). The clinometer is 10 cm long. M&E-GN85-CS4-5*

In subunits 3b, 3e and 3x, plagioclase is commonly bimodal in grain size, and rare, tabular megacrysts up to 40 cm long are scattered in a coarse to very coarse grained groundmass; the megacrysts are aligned parallel to the layering. Thick anorthosite layers, in which layering and lamination may be more common than is apparent because of the monomineralic composition, also occur in these three subunits, and may be related to subunit 3i (see below). These layers commonly contain residual patches of coarser grained, intergranular-textured leuconorite and norite, which suggests an affinity with the noritic associations. Rarely, blocks of leucotroctolite, and oxide pods and layers occur in subunit 3x(e).

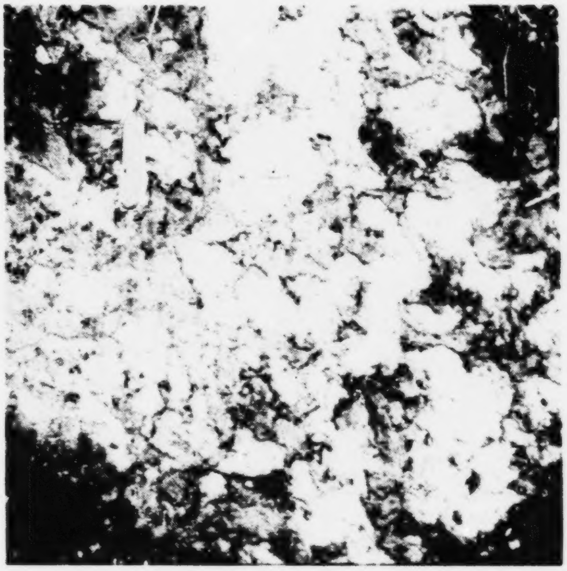


Plate 9: *Very coarse grained isotropically textured norite (subunit 3g); plagioclase is mostly polygonized, some of the orthopyroxene is kinked. The penknife is 9 cm long. M&E-SW85-CS1-34.*

Plate 10: *Medium grained intergranular-textured leuconorite (subunit 3f) containing a laminated anorthosite xenolith. The hammer is 33 cm long. M&E-SW85-CS2-11.*

Several anorthosite-related bodies occur in the other rocks of the massif. In its southwestern part, the massif is cut by medium to coarse grained, seriate, intergranular-textured norite and leuconorite (subunit 3f), and a very coarse grained, texturally similar, but homogeneous, noritic equivalent (subunit 3g, Plate 9). These rocks are common in and around the Atikonak River valley in this area. Every gradation occurs between isotropically-textured norite and leuconorite containing scattered xenoliths of subunits 3b, 3e and 3x (Plate 10), through increasingly xenolith-rich facies, to a host rock composed of subunits 3b, 3e or 3x that is cut by norite and leuconorite dikes or net-veins. The intrusive rock types are distinctly brown weathering in relation to their dominantly anorthositic xenoliths. Subunit 3i consists of a medium to coarse grained, generally isotropic, anorthosite containing gray to brown, commonly chatoyant plagioclase.

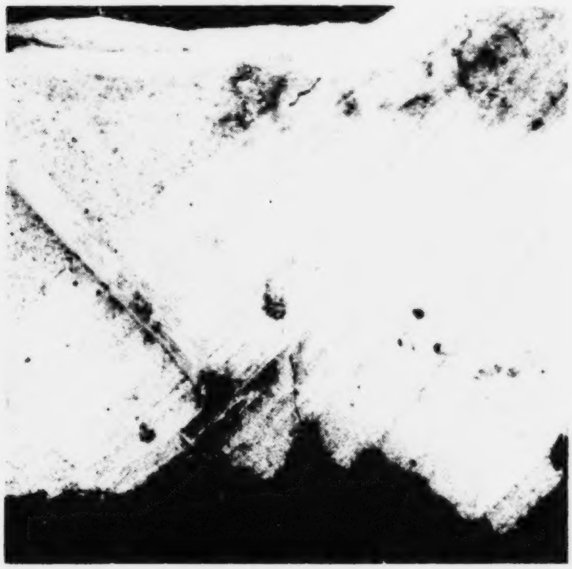


Plate 11: *Layered ferrodiorite (subunit3k), containing centimeter- to decimetre-scale layers of varying color index and rare mineral grading (tops toward the bottom right). The hammer is 33 cm long. M&E-SW85-CS2-9.*

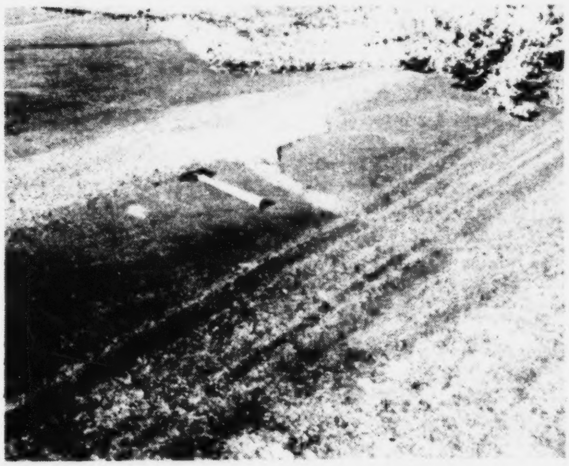


Plate 12: *An appendage from an anorthosite layer cuts across a layered sequence of leucotroctolites and dies out within it (subunit 3a). Layers dip about 55 degrees to the upper left (west); the relationship is consistent with a mild disturbance during bottom crystallization in which an overlying anorthositic cumulate penetrated already consolidated underlying cumulate rocks in a manner reminiscent of clastic dike formation. The hammer is 33 cm long. GSC-203423-M.*

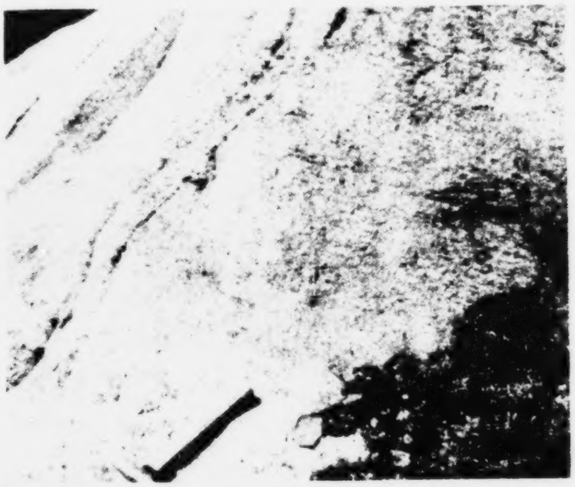


Plate 13: *Strong planar plagioclase orientation in a coarse grained troctolite layer overlying a very coarse grained anorthosite layer, also with marked planar plagioclase orientation (subunit 3a). The hammer is 33 cm long. GSC-203423-G.*

The anorthosite is dark gray in the north (NTS map area 23A), but is light gray to white in the lower-lying exposures farther south (NTS map areas 22P/9 and 15). Lamination is rare and the anorthosite locally contains primary biotite. It is not known whether this subunit is intrusive or whether some or all of the occurrences are large xenoliths.

A medium grained, layered intrusion containing olivine gabbro, troctolite, and gabbro is named the Beaver Pond gabbro (subunit 3j). Local pyroxene- and oxide-rich pods or disrupted layers in the intrusion contain up to several percent sulfides, including pyrrhotite and chalcopyrite. The Beaver Pond gabbro appears to intrude coarse grained leucotroctolite (subunit 3a) and is intruded by pyroxene monzonite (Unit 4).

Ferrodiorite forms another small, discrete pluton (subunit 3k, Plate 11). It is a fine to medium grained, light-brown weathering rock rich in magnetite and orthopyroxene, with a well developed, commonly contorted layering. The ferrodiorite contains a xenolith of anorthosite and is intruded by dikes of norite (subunit 3f).

Internal structures of the massif. Mineral layering, commonly accompanied by moderate to strong sub-parallel planar plagioclase lamination, is developed to some degree in nearly all of the subunits of the massif (Plates 6, 8, 10, 11, 12 and 13), excluding only subunits 3f, 3g and 3i. In addition, layers defined by differences in plagioclase grain size and shape occur independently and in association with mineral layers (Plate 13). Examples of mineral- graded layers (Plate 11), grain-size-graded layers, cross-bedded layers, and apparent slump features all occur in different localities. Modal contrasts between adjacent layers are commonly subtle, involving variations of less than 20 percent in amounts of mafic components present (e.g., lower right in Plate 12). Locally, however, stronger contrasts occur and melatroctolite (color index, >50) and oxide-rich layers are present in a few localities.

Mineral grading determinations consistently indicate tops to the east in the east part of the map area, within subunit 3e. This indicates that the orthopyroxene-bearing subunits 3e and 3h probably overlie subunits 3a and 3d, and that the transition group (subunit 3c) and rare layers of subunit 3a occur near the base of subunit 3e. The layered, equigranular-textured noritic rocks (subunit 3e) could either be a precursor to the cross-cutting noritic rocks in NTS map area P/15 (subunits 3f and 3g), or be fed by them.

Planar plagioclase orientation is commonly developed in rocks that lack mineral layering and is present in olivine- and orthopyroxene-bearing rocks, as well as nearly pure plagioclase rocks (Plate 13). Where sections subparallel to dip surfaces are exposed, it can be seen that plagioclase crystals are plate-like or discoidal, and in places are packed closely together like brickwork with only very small amounts of interstitial material. Planar plagioclase orientation occurs in rocks of grain sizes less than 1 cm to greater than 30 cm, and it locally occurs either throughout a layered section, or is limited to specific layers and is absent or much more weakly developed in intervening layers.

Oxide-rich pods, clots and layers (up to 1 m thick) occur locally, mostly in subunits 3e, 3j and 3k, and most are strongly magnetic, indicating a preponderance of magnetite over ilmenite. Opaque oxide minerals are usually the second most abundant mafic constituent present in any one lithotype and disseminated grains of oxide are visible in many specimens. In subunit 3h magnetite is the predominant mafic mineral; orthopyroxene is subordinate. Clots of massive opaque oxide up to 30 cm across occur sporadically in some noritic and leuconoritic outcrops, in places closely associated with coarse grained orthopyroxene and small amounts of sulfides.

Complex interrelationships occur among subunits on a local scale. A consistent relationship in the northwest, however, is that xenoliths of coarse grained to very coarse grained anorthosite and leuconorite are present in many outcrops of troctolite and leucotroctolite. Xenoliths range in size from less than 1 m to at least 10 m across and are possibly much larger. These relationships clearly show that orthopyroxene-bearing rocks predate and postdate the troctolite association, although the latter case is more common at the present level of exposure.

Very coarse grained to 'giant' orthopyroxene crystals occur widely in the massif, commonly ranging from 30 to 60 cm across (Plate 14). These include both rounded or nodular shapes, and crystals subophitically intergrown with plagioclase. Where these large orthopyroxenes are present within sections of olivine-bearing rocks, they occur within very coarse grained anorthosite or leuconorite that is commonly identifiable as xenoliths. Giant orthopyroxenes were not found in direct contact with troctolite or leucotroctolite, implying that they became unstable in silica-deficient magmas at crustal pressures and survived transport only where they are armored by an enclosing xenolith. Very coarse grained, commonly kinked, orthopyroxene crystals also occur in residual patches and as groundmass (heteradcumulate?) plates in subunit 3e.

Plate 14: *Strong kink banding in a giant orthopyroxene crystal (subunit 3a); the crystal is over 40 cm across. GSC-203423-I.*

Although layered structures occur widely, the massif does not have an overall coherent pattern of layering. Areas up to 50 km² do show regular attitudes of layering. However, it is not possible to determine to what extent layer domains represent discrete intrusions, as opposed to disrupted, tilted or deformed parts of a larger intrusion because over considerable areas rock compositional changes are subtle. Intrusive relationships are visible in outcrop in many places (e.g., subunits 3f, 3g, 3j and 3k and the many examples of cognate xenoliths in subunit 3a), lending some support for interpreting the massif as a composite of numerous separate intrusions.

Aplite, fine to coarse grained granite and granite pegmatite dikes and veins are common in the massif, particularly in the northeastern and eastern parts of the map area. Some of these relate to the emplacement of the various granitoid plutonic rocks; most, however, probably relate to intrusion of partial melts, generated during regional metamorphism of the envelope to the massif, along tensile or shear fractures in the anorthositic rocks. At one locality the granite veins contain pyrogenetic sillimanite. Some dikes and veins have amphibolite facies alteration halos, up to 10 cm wide, in the anorthositic rocks.

Monzonite-Related Rocks (Unit 4)

Immediately adjacent to the northwestern margin of the Atikonak River massif, and in intrusive contact with it, is a rim of medium to coarse grained pyroxene monzonite, pyroxene quartz monzonite and minor quartz diorite. These rocks are typically brownish to rusty weathering, commonly with a color index of 20-30. Variable amounts of amphibole and biotite accompany, and locally exceed, pyroxene in these rocks. Perthite megacrysts, 1 to 3 cm across, become increasingly abundant away from the massif contact. At one locality, the unit contains a body of finer grained monzonite, which is chilled against the main phase, and a xenolith-rich facies. The xenoliths consist mostly of fine grained and porphyritic equivalents of the main phase in which the K-feldspar phenocrysts closely match those of the host, and also include granoblastic leucogabbroic clasts that look like deformed cumulate rocks. Several small, subequant areas of monzonite occur in southern parts of the map area. Dikes of pyroxene monzonite, ranging from 1 to 30 cm in width, intrude the Atikonak River massif to at least 5 km from the northwestern contact, and more locally around the southern monzonite intrusions.

Granitoid Plutonic Rocks (Unit 5)

Subunits 5a and 5b occur together in the west part of NTS map area A/2; their interrelationship is unknown. Subunit 5a consists mostly of equigranular, fine to coarse grained, pink or maroon, biotite granites that vary in color index from 0 - 10. Anhedral, seriate and saccharoidal primary textures are present and the granites range from undeformed to moderately foliated. Aplite veins are common and the fine to medium grained granites are locally riddled with quartz veins.

Subunit 5b comprises K-feldspar megacrystic granitoid rocks that are chiefly quartz monzonite in composition. The rocks are pink or buff (color index, 3 - 10) and range from undeformed to strongly foliated. Megacrysts, 1 to 3 cm across, occur in a groundmass of quartz, plagioclase, K-feldspar and biotite. Biotite is commonly intergrown with plagioclase, and quartz is commonly moulded on plagioclase in an otherwise anhedral fine to medium grained groundmass. Sphene and allanite are accessory phases; the former is locally abundant. The subunit contains veins of aplite and granite. The small area of megacrystic granite, 9 km northeast of the main outcrop area of subunit 5b, contains inclusions of paragneiss (subunit 1a).

A large mass of coarse grained biotite- and/or hornblende-bearing granite to quartz syenite (subunit 5c) that has a distinctive rapakivi texture formed by plagioclase-rimmed perthite ovoids of 4 cm or more in diameter, lies to the northwest of the monzonitic rim to the Atikonak River massif; in several places subunit 5c appears to be transitional into the pyroxene-bearing monzonitic rocks. Large parts of the rapakivi granite that occur close to the anorthositic massif are essentially massive with negligible deformation of original igneous textures (Plate 15) and variable polygonal recrystallization of the original mineralogy. Farther northwest, the rapakivi texture becomes increasingly obscure, biotite predominates over hornblende, and garnet, commonly associated with opaque oxide grains, is ubiquitous wherever the quartz syenite or granite is recrystallized. Within 6 to 12 km of the massif contact, subunit 5c is penetratively deformed and recrystallized with a shape fabric of polygonal K-feldspar and ferromagnesian-rich clots.

Subunit 5d consists of finely to coarsely K-feldspar porphyritic granite that is characterized by blue quartz. In the finer grained variety, 10 to 40 percent of tabular, gray, K-feldspar phenocrysts are either distributed with random orientation or form a primary foliation in an anhedral, medium grained granite groundmass. In the more abundant megacrystic variety, subequant K-feldspar phenocrysts are generally a dark purplish gray, 1 to 4 cm across, and commonly form 30 to 60 percent of the rock. Locally, the megacrysts are concentrated in patches, in which the interstitial material is minor, and poorly developed rapakivi textures are also present. The groundmass is medium to coarse grained granite. The granite varies toward quartz-poor compositions and locally contains abundant, fine grained, ovoid xenoliths of dioritic to monzonitic composition. The subunit is cut by coarse to very coarse grained graphic granite dikes and aplite veins. Non-megacrystic, blue-quartz granite, probably related to subunit 5d, forms dikes in the adjacent anorthositic rocks.

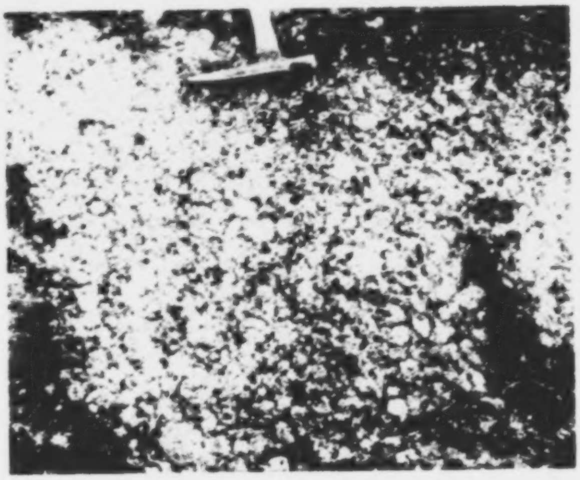


Plate 15: *Coarse grained, ovoid-rich, massive rapakivi granite (subunit 5c). The hammer head is 16 cm across. GSC-203423-J.*

Pink, equigranular, fine to coarse grained biotite granite (subunit 5e) is abundant southeast and east of the centre of the map area. The granite is rarely K-feldspar ± plagioclase porphyritic and ranges from undeformed to moderately foliated. Rare, equigranular to aplitic, granite layering may represent migmatization or the intrusion of veins. Locally the rock is seriate-textured or contains xenoliths of diorite or granite gneiss.

To the north and east of the equigranular granites, pink, K-feldspar megacrystic rocks (subunit 5f) are predominant, although the two rock types are intimately associated at map scale. The megacrystic rocks include granite, quartz monzonite and quartz syenite. K-feldspar megacrysts, generally 2 to 3 cm across, but locally up to 7 cm, occur in a medium to coarse grained groundmass of quartz, plagioclase and biotite, including minor magnetite and allanite. This subunit ranges from undeformed to gneissic, although the layering in the gneissic portion may be the result of extreme deformation of K-feldspar megacrysts rather than migmatization. Pink or white, coarse to very coarse grained alkali-feldspar granite, granite and quartz syenite sheets also occur in this area. They are commonly rich in allanite. The sheets crosscut finer grained granitoid rocks, granitoid-layered amphibolite and tonalite gneiss.

Subunits 5e and 5f contain abundant enclaves and schlieren of amphibolite, and lesser, but morphologically similar, amounts of plagioclase-biotite rock and tonalite gneiss, all of which belong to subunit 2e. A K-feldspar porphyritic granite (part of subunit 5e) intrudes the anorthosite suite west of Lac Thevet, and granitic gneiss dikes (subunit 5g) cut the anorthosite suite, the tonalite gneiss and strongly foliated to gneissic portions of subunit 5f in various parts of this eastern area.

Gabbro (Unit 6)

Several patches of gabbro occur within the rapakivi-textured granitoid rock in the north part of the map area. Where the granitoid rock is undeformed, the gabbro is a dark, medium grained, intergranular-textured rock containing a largely primary mineralogy. Farther north, the gabbro patches consist of fine to medium grained, foliated amphibolite, commonly containing disseminated garnet. It is not known whether the patches are inclusions or intrusions in their rapakivi-textured host.

Quartz-Feldspar Porphyry (Unit 7)

This unit crops out as a single cliff exposure in the southeast part of the map area and is depicted as underlying the whole of the hill. The porphyry is an undeformed, fine grained, quartzofeldspathic rock containing quartz and feldspar phenocrysts approximately 0.5 cm across. Its contacts were not seen.

Diabase Dikes (not on Figure 3)

Diabase dikes are black, very fine grained and aphyric, and probably are of more than one generation. They are known only to occur in the areas underlain by paragneiss and anorthositic rocks in the map area. The dikes are generally less than 1 m wide, discordant to the gneissosity and rectilinear, but locally are subparallel to the fabric and more irregular in thickness. They commonly have chilled margins and rarely are backveined; bayonet and *en echelon* structures are developed in places. One example was found of a straight, discordant, apparently unmetamorphosed dike with a 1 cm wide foliated margin.

Surficial Geology (not on Figure 3)

The map area was completely covered by late Wisconsin ice of the Laurentide ice sheet. Numerous striae, grooves and roches moutonnées indicate that the advance was generally from a northwesterly direction. Till cover is still very extensive in the lowland parts of the map area, but the initially thinner or discontinuous cover in many of the upland areas is considerably depleted by erosion, particularly on the main plateau north and west of the Atikonak River, and in the east-trending section of the Atikonak River valley. The lowland till locally forms a complete cover, even of prominent hills, in the lee of the main plateau, and a till veneer occurs on some of the highest ground along the watershed in NTS map area P/10.

The till cover is punctuated by 1 to 4 km wide outwash plains and associated eskers that record the pattern of late Wisconsin deglaciation, mostly in a 150-trending direction. The outwash plains provide the source for extensive areas of aeolian sand. These deposits nucleate along short sections or lengthy bands of the outwash plains and extend eastward for up to 6 km, generally terminating in lobate forms. The aeolian sand is characterized by dune morphologies (M. Batterson, personal communication, 1985) indicating paleowind directions ranging from west-northwest to west-southwest. The dunes consist of angular-nosed, barchan-like forms that commonly interfinger to form obliquely longitudinal dune fronts. The dunes are in various stages of stabilization and are only rarely still active.

STRUCTURE AND METAMORPHISM

Units 3 and 5 separate and isolate several areas containing older structures, e.g., Units 1 and 2. As a result the map area is divided into four structural subareas (shown in an inset with Figure 3) between which firm correlations cannot presently be made.

I. Northwestern Subarea

The paragneiss contains a well developed migmatitic layering (Plate 1) that, locally, has coalesced to form a diatexite. The migmatization in the paragneiss sequence is the oldest tectonometamorphic event recognized in the map area. Relicts of the mineralogy associated with this initial metamorphic differentiation have escaped subsequent recrystallization, and consist of restite clots of sillimanite and opaques and coarse grained granite layers. The paucity of biotite in both the leucosome and the restite indicates an intense dehydration at this time and the general lack of ferrous iron-bearing phases (e.g., garnet, biotite and orthopyroxene), together with an abundance of magnetite, indicates a high oxygen fugacity during metamorphism (T. Rivers, personal communication, 1983). Low water pressure and high oxygen fugacity may have inhibited partial melting (Emslie, 1981) and the earliest recognized migmatitic layering may be an enhanced primary feature. The high oxygen fugacity may have resulted from high ferric iron contents in the depositional environment (A. Thomas, personal communication, 1984) and this condition has persisted, at least in part, through subsequent metamorphism.

In the northwest part of the map area, the formation of a gneissosity in the basic gneiss, and probably the supracrustal rocks as a whole, was followed by the emplacement of basic plutonic rocks (subunits 2a and 2b). Units 1 and 2 in this region were then deformed together during a major high-grade dynamothermal event. This resulted in tight folding and a largely penetrative, axial planar recrystallization in the paragneiss, which occurred at sillimanite grade (Plate 1). Minor hydration of the restite and a local lowering of the oxygen fugacity resulted in the formation of biotite seams and selvages and garnet crystallization, perhaps involving reactions such as:

$$\text{Ksp} + \text{mt} + \text{water} \rightarrow \text{bio} + \tfrac{1}{2}\,O_2$$

$$2\ \text{sill} + 2\ \text{mt} + 4\ \text{qz} \rightarrow 2\ \text{gt} + O_2$$

The gabbroic and noritic rocks were heterogeneously deformed and their recrystallization produced two-pyroxene, biotite, plagioclase and quartz mineral fabrics.

The foliations strike mostly between 090 and 045, dip steeply toward the north-northwest and have steeply pitching lineations. High-strain zones are marked by mylonitic or porphyroclastic textures with higher biotite contents than those normally found in the paragneiss; they commonly occur in the paragneiss adjacent to the plutonic rocks.

Recrystallization outlasted the deformation and mimetic, posttectonic crystallization structures involving biotite, garnet and sillimanite are common in the paragneiss (see reactions above). Metamorphic sweats and granitic veins are mostly syn to posttectonic in the basic rocks and commonly contain orthopyroxene (Plate 3).

No distinction was made in the field between the biotite-poor, relatively anhydrous, paragneiss assemblage (subunit 1a) that occurs in both the northwestern uplands and in the adjacent lowland areas. However, the mineralogy of the basic plutonic rocks and, in particular, the orthopyroxene-bearing segregations and granitoid sheets within the basic rocks, indicate that the upland areas are underlain by granulite facies rocks. In contrast, the more hydrous, biotite-rich facies of the paragneiss (subunit 1b) is thought to be a middle to upper amphibolite facies assemblage and is found only in lowland areas. This is consistent with observations made to the north (1982 and 1983 areas in Figure 1), namely that the major changes in topography represent metamorphic facies changes (Stevenson, 1968; Nunn and Christopher, 1983; Nunn, Noel and Culshaw, 1984). In most cases it is not known if these facies boundaries also coincide with structural breaks.

Both the gneissic location fabric in the paragneiss and the axial planar mineral foliation throughout Units 1 and 2 in the northwest part of the map area are folded into a large, regional synform (Figure 3). Variations in the attitudes of the fabrics indicate that the structure is probably synclinorial and small-scale minor folds are common. The smaller-scale structures are locally coaxial with the earlier mineral lineation but little recrystallization is apparent during this later episode of folding.

Granitoid plutonic rocks (subunits 5a, 5b and 5c) underlying the lowlands in the northwestern part of the map area contain paragneiss inclusions and are weakly to strongly foliated. The foliation is defined by quartz, feldspar and biotite groundmass mineral fabrics, shape fabrics of ferromagnesian clots and polygonized feldspar aggregates, and, less commonly, megacryst alignment. Assemblages containing garnet biotite and hornblende occur in both deformed and undeformed (but recrystallized) rock and indicate amphibolite facies conditions.

The foliation in the granitoid rocks trends mostly between 100 and 050; in the west it generally dips moderately to the north whereas east of Butterfly Lake it dips moderately to the southeast and contains a down-dip linear component. The fabrics in the rapakivi-textured rocks become less pervasive southeastward and pass through a zone containing variably oriented, narrow shear zones into undeformed rock near the anorthosite suite contact. Locally, the undeformed rock is recrystallized and the ovoids are replaced by a polygonal aggregate of K-feldspar. There is no correlation between recrystallization of the ovoids and deformation, but there does appear to be a general relationship between the degree of deformation and the height of the terrain, i.e., the lower levels are underlain by the most deformed rocks and higher levels are underlain by undeformed rocks, near the anorthosite contact.

Perturbations in the foliation in the granitoid rocks appear to relate to cross-folding in the east part of NTS area A/7, and oval domes and basins in the west part of NTS area A/2; both structures have approximately 140-trending axial traces.

II. Southwestern Subarea

In the southwest (NTS map areas P/10 and 15), a similar relationship is thought to exist between the paragneiss (subunit 1e) and basic plutonic rocks (subunit 2c) as in the northwestern subarea. Here, however, the metabasic rocks were emplaced concordantly and are not known to cross-cut the paragneiss layering.

The paragneiss has a folded gneissosity to which there is a silllimanite-grade axial planar fabric. Rare agmatite zones are developed in the paragneiss and a plagioclase shape fabric occurs in a cumulate layer in the basic rocks; both are thought to be coeval with the axial planar fabric.

The main area of paragneiss in the southwest part of the map area (subunit 1e) is characterized by the anhydrous type of restite (cf. subunit 1a), which here contains orthopyroxene, and the metabasic rocks (subunit 2c) are at granulite or pyroxene hornfels grade. Fabrics in this paragneiss are oriented east-northeasterly and are generally steeply dipping; near the anorthosite contacts the paragneiss and metabasite structures dip gently away from the contact. Farther north in NTS map area P/15, the smaller pendants of paragneiss contain the more hydrous assemblage (subunit 1b).

Some paragneiss layers in subunit 1e contain abundant cordierite. The mineralogy appears isotropic in these layers, as well as in much of the quartzofeldspathic layers, some sillimanite-bearing restites and the adjacent metabasic rocks. This may be due to thermal recrystallization during emplacement of the anorthosite suite (Unit 3) with cordierite produced by replacement of the restite. Alternatively, the cordierite could be a product of compositionally controlled regional metamorphism, and the lack of pyroxene, sillimanite and quartzofeldspathic mineral fabrics may be related to posttectonic recrystallization. Cordierite probably formed from biotite-free, biotite-poor and biotite-rich assemblages respectively, according to the following reactions:

$$2\ \mathrm{mt} + 6\ \mathrm{sill} + 9\ \mathrm{qz} \rightarrow 3\ \mathrm{cord} + O_2$$

$$\mathrm{bio} + \mathrm{mt} + 6\ \mathrm{sill} + 9\ \mathrm{qz} \rightarrow 3\ \mathrm{cord} + \mathrm{Ksp} + H_2O + \tfrac{1}{2}\ O_2$$

$$2\ \mathrm{bio} + 6\ \mathrm{sill} + 9\ \mathrm{qz} \rightarrow 3\ \mathrm{cord} + 2\ \mathrm{Ksp} + 2\ H_20 + 0_2$$

Orthopyroxene could also be the result of thermally induced reactions in the southwestern pendant.

The anorthositic rocks (Unit 3) were followed by emplacement of the granitoid suites 5c and 5d. In this area, Units 3 and 5 are rarely foliated. These deformation fabrics strike westerly in Unit 3 and northwesterly in Unit 5, and dip in either direction. The orientation (gently inward-dipping) of the paragneiss structures near the anorthosite contact around the southwestern pendant, and the undulating, gentle to moderate dips of the layering and lamination in the underlying anorthosite, suggest that the paragneiss is now a synformal cap resting upon the anorthosite suite (Figure 3).

III. Atikonak River Massif

Structures such as layering and igneous lamination in cumulate intrusions are generally regarded as primary features of initially low dip or subhorizontal attitude. In the Atikonak River massif, these features are now of very variable orientation and include large areas underlain by subvertical and even overturned layering. Strong deformation in the massif is confined to a number of shear zones (mostly narrow), and the absence of penetrative deformation in the massif indicates that much of the variation was achieved by brittle deformation, e.g., fracturing, block faulting or fracture-assisted buckling. The extent to which these structures may have been superimposed on original variations relating to possible multiple intrusion is unknown. A major 055-trending fault is inferred in the northeast part of the map area, based upon a sinistral displacement of 1 to 3 km of the interlayered subunits.

On a local scale, narrow, white-weathering, hairline fractures occur widely in the more massive rocks of the massif. The fractures are filled with altered material, including radiating crystal clusters that lie in the plane of the fracture and spaced garnet porphyroblasts up to 2 cm across that have nucleated along the fractures in some areas. Most of the fractures show little or no offset but relative displacements up to a few metres can be seen in places. The distribution of these fractures is not uniform throughout the massif and they appear to be more abundant toward the northwest margin of the body, and in the more pristine anorthositic rocks in southern parts of the map area (NTS map area 22P).

Throughout the massif, but far more commonly away from the northwestern upland plateau and the massive fractured areas, grain boundary recrystallization of plagioclase is evident and is locally penetrative. This feature makes some laminated anorthosites (e.g., parts of subunit 3h) look as if they contain strong, anastomosing, tectonic fabrics. Although the recrystallization is probably due to annealing of strains produced tectonically, e.g., by grain boundary sliding, the amount of strain may be negligible. This polygonization is probably responsible for the generally lighter gray or white weathering colors, and for a decreased resistance to erosion of rocks in the Atikonak River valley and lowland areas of the massif. The grain-boundary recrystallization and the hairline fracturing may be, respectively, ductile and brittle responses to the same tectonic stresses.

Shear zones in the Atikonak River massif are generally only several millimetres to a metre across, but are widespread. Within shear zones, plagioclase is recrystallized to fine to medium grained granular aggregates. In rocks of troctolitic association, olivine is replaced by a hydrous mineral fabric of amphibole and biotite; in noritic rocks, orthopyroxene is commonly enclosed in a sheath of biotite and is locally completely replaced by the biotite. Shear zones confined to granitic veins are common in the Atikonak River massif. The shearing occurs either throughout the veins, along the margins, or in the centre of the veins, and is evident as strong, steep, linear fabrics of quartz, feldspar and biotite.

The largest shear zone in the massif follows the Romaine River in the northeast corner of the map area (Figure 4). The zone strikes north-south, dips steeply to the west and is 1 to 3 km wide. Structures within the zone range from foliated rock with abundant lenticular relicts of gray or red-brown plagioclase, to a fine grained, white, anorthosite gneiss. In places, this lenticularity occurs at larger scales, and augen of undeformed and partly recrystallized rock occur in a mesh of anastomosing shear zones. Relict pyroxenes with biotite sheaths are common, and both shape fabrics and mineral lineations indicate an approximately down-dip extension.

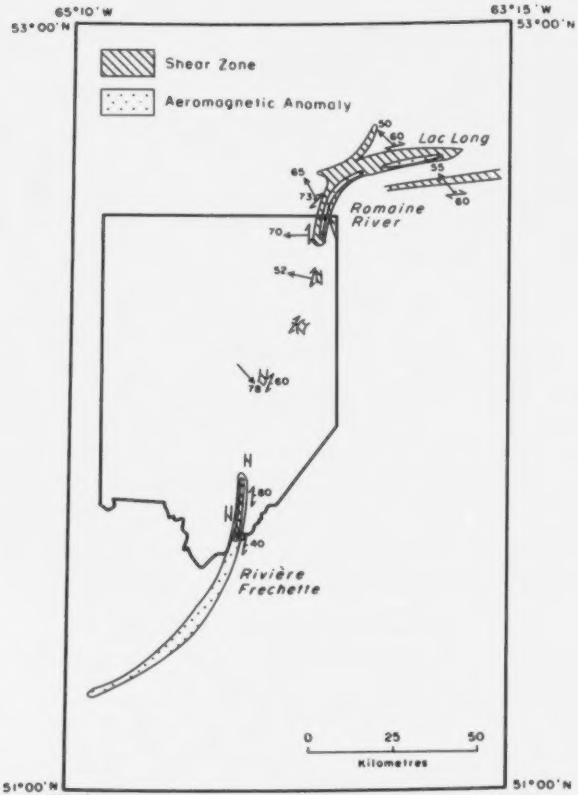


Figure 4: *The Lac Long/Romaine River shear zone system, the Rivière Frechette shear zone and its proposed aeromagnetically-interpreted extension, and a possible connection between the two shear zones [in part after Thomas et al. (1984) and Nunn et al. (1984); aeromagnetic data from Geological Survey of Canada, (1985)].*

Farther south, well spaced groups of outcrops containing similar strong fabrics occur more or less on line with the Romaine River zone, although the orientations of the fabrics are very variable. These outcrops are thought to represent folded continuations of the Romaine River zone, and are tentatively interpreted to join with the Riviere Frechette zone in subunit 2d (see below). Several smaller, subparallel shear zones are suspected in eastern parts of the map area.

Metamorphic overprinting is evident on rocks of the massif but its significance is not readily assessed. Whereas all the semi-brittle to ductile deformation of rocks in the massif is accompanied by metamorphism, the converse is not the case and large areas of undeformed rock are pseudomorphed by a metamorphic mineralogy. These areas are characterized by corona-forming reactions. Coronas separating olivine and plagioclase are nearly universal in olivine-bearing rocks, but it is unclear whether these are a consequence of subsolidus cooling of a deep-seated intrusion or result from younger regional metamorphism. Typical coronas are narrow and extremely fine grained; field examination suggests two pyroxenes and spinel are probably present. Locally, in the north part of the map area (NTS map area 23A), and usually adjacent to shear zones or pegmatitic granite dikes, reaction rims and coronas become broader and their mineralogy changes to fibrous amphibole, chlorite, and other hydrous minerals. In places, pyroxene or olivine are completely replaced, although they can usually be readily identified by their hydrous pseudomorphs. In southern areas (NTS map area 22P) such replacements are more complete and widespread, and identifiction of the protolith is more difficult (subunit 3x). The distribution of the hydrous type of coronas also correlates well with the generally lower-lying areas of the massif.

IV. Southeastern Subarea

The paragneiss is very poorly exposed in the southeastern part of the map area. It contains a gneissosity and a subparallel, sillimanite-bearing, mineral recrystallization of hydrous aspect (subunit 1b).

The basic plutonic suite is moderately to strongly foliated, exhibiting granulite facies (subunit 2d, Plate 4) or amphibolite facies (subunit 2e, Plate 5) dynamic fabrics. The facies boundary is shown in Figure 3. Locally, subunit 2e consists of either tonalitic gneiss or amphibolite that is either veined or layered by granitoid rocks; these location fabrics are in the amphibolite facies. The foliation throughout the suite is mostly steep, oriented between 000 and 040; and in the gabbronorite (subunit 2d) it commonly contains a steeply north-plunging, linear component.

The consistency of the foliation throughout subunits 2d and 2e suggests that the facies boundary is synchronous with the foliation and not a result of structural reworking. The mapped facies boundary is close to a marked aeromagnetic change from high in subunit 2d to low in subunit 2e (Geological Survey of Canada, 1985). The presence of foliated amphibolite dikes (Plate 4) within the gabbronorite also indicates that the mineral assemblage is locally dependent upon the available water fugacity; in hand specimen, no reaction rims are visible at the dike margins.

Subunit 2d is intruded by the anorthositic rocks (Unit 3) but the relationship of Unit 3 to the fabrics in the metabasic rock is unknown. Both basic suites (subunits 2d and 2e and Unit 3) are intruded by granitoid rocks (subunits 5e and 5f) of which weakly to undeformed rocks cut the fabrics in subunit 2e.

Fabrics in subunit 5e range from isotropic, through quartzofeldspathic and biotite mineral foliations, to a spaced location fabric of aplitic veins. In subunit 5f, they range from isotropic, through mineral and shape aggregate foliations, to gneissic. Locally, a discontinuous layering, formed by attenuation of a replaced megacryst shape fabric, is folded. Rarely, subunits 5f and 2e and Unit 3 are cut by granitoid gneiss dikes (subunit 5g). All the structures in the southeastern granitoid plutonic suite are in the amphibolite facies. The structures strike mostly between 080 and 150 and are variably dipping.

A 0.5 to 0.8 km wide shear zone (the Rivière Frechette shear zone, Figure 4) cuts the gabbronorite in the southernmost part of subarea IV. The zone consists of varying sizes and concentrations of foliated, gabbronorite augen in an anastomosing mesh of fine grained, amphibolite facies shear zones. The shear zone grades into mylonite and ultramylonite but lacks a well developed linear fabric. Locally, the mylonite fabric is folded into outcrop-scale, angular-hinged folds. Less than 1 km north of the approximate facies boundary between subunits 2d and 2e (Figure 3), the shearing heterogeneously deforms amphibolite that is veined and diked by granitoid rocks. Five kilometres west of Lac Thevet, mylonitic granite containing rare, porphyroclastic feldspar relicts cuts granite-layered amphibolite (subunits 5e? and 2e), and is also folded.

The Romaine River - Rivière Frechette Shear Zone

The Lac Long lineament (Thomas *et al.*, 1984) occurs to the northeast of the map area (Figure 4), where it consists of a zone of straightened paragneiss and deformed anorthositic rocks. This shear zone trends southward near the boundary of the map area and follows the Romaine River as a 1 to 3 km wide zone of deformed anorthositic rocks. Despite the lack of exposure and opposing dip directions between the north and the south of the map area, it seems likely that this deformation zone is continuous with the Rivière Frechette shear zone (Figure 4). Both the Lac Long/Romaine River and the Rivière Frechette shear zones show as marked aeromagnetic lows, although a connection between the two is not obvious on the aeromagnetic map (Geological Survey of Canada, 1985). The significance of this potentially greater than 200 km long structure (Grenvillian?) is unknown.

Late Structures

Throughout the map area, foliations vary considerably in both dip and strike; this irregularity particularly applies to the southeastern granitoid rocks, which are the youngest of the main plutonic suites in the map area. Crenulations and fracture cleavages associated with these variations are very rare.

Brittle features also occur throughout the map area. They consist mostly of fault sets, of which northwest-trending fractures with a subvertical throw are prominent. Most rock types in the map area are cut by rare pseudotachylite and/or ultracataclasite veins.

MINERALIZATION

Disseminated metallic minerals occur throughout the map area. These consist mostly of magnetite, pyrite and pyrrhotite (Pyke, 1956) in the paragneiss (Unit 1); magnetite, ilmenite and pyrite in the Atikonak River massif (Unit 3); and magnetite in the basic plutonic suites (Unit 2), the monzonites (Unit 4) and the granitoid plutonic suites (Unit 5). The monzonite rim to the anorthositic massif shows as a prominent aeromagnetic ridge (Geological Survey of Canada, 1985), but large concentrations of magnetite were not found.

Concentrations of oxide and sulfide minerals occur in some rock types in the Atikonak River massif. Podiform or layered concentrations, up to 1 m across, of 30 to 100 percent magnetite occur in the noritic rocks (subunit 3e), particularly in the east part of the massif, and less commonly in subunits 3a and 3h. Magnetite-rich layers, containing orthopyroxene, occur in the ferrodiorite (subunit 3k). The Beaver Pond gabbro (subunit 3j) contains pods or layers rich in oxides and sulfides including pyrite, chalcopyrite and pyrrhotite.

Chatoyant feldspar is widepread in the plagioclase-rich rocks of the Atikonak River massif, principally in subunits 3e, 3i and 3x, displaying varying hues of blue, green, yellow and bronze. In some leuconoritic rocks of subunit 3e, irridescent plagioclase occurs in medium grained, granular, polygonally recrystallized, metamorphic derivatives of the host rock, as well as in the much coarser grained protolith.

Pure anorthosite suitable for alumina production is not abundant. Aggregate resources associated with outwash material are voluminous, however, accessibility precludes development.

DISCUSSION

The northwestern part of the map area appears to be a direct continuation of rock units mapped to the north (Nunn *et al.*, 1984) and lies within the Lac Joseph allochthon (Rivers and Nunn, 1985). The geochronology-based history set up for that area places the gneissic fabric development in the early Labradorian, the basic suites in a plutonic interval, and the major mineral recrystallization in both the upland paragneiss and the metabasic rocks in the late Labradorian (Nunn *et al.*, 1985). The Labradorian orogeny and the related plutonic interval occurred between 1700 Ma and 1600 Ma (Nunn *et al.*, 1985; Thomas *et al.*, *in press)*. Foliations in the granitoid rocks, and perhaps the post-gneissosity foliation in the lowland paragneiss, are thought to be Grenvillian in age.

The age of the anorthositic rocks is poorly known. The Atikonak River massif has yielded a K-Ar (biotite) age of 854 ± 31 Ma (Wanless *et al.*, 1970, page 65). The massif and its associated granitoid rocks (subunits 5c and 5d) were emplaced between the Labradorian orogeny at ca. 1660 Ma and the Grenvillian orogeny at ca. 1000 Ma.

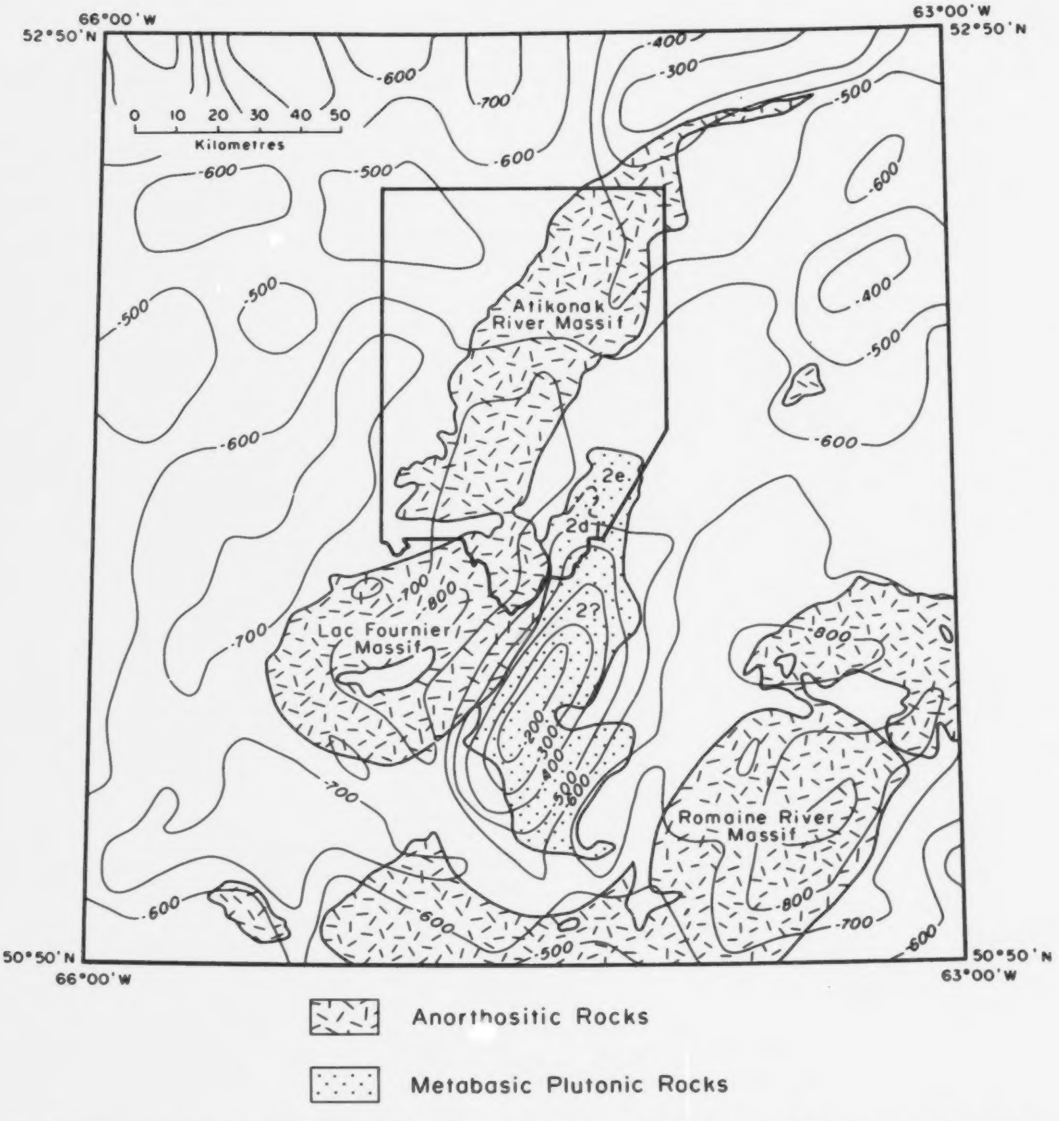
The generation of anorthosite magmas relates to mantle processes (Emslie, 1985).The tectonic setting of the Atikonak River massif at the time of intrusion is not understood at present. The rock assemblage, however, is virtually identical to anorogenic associations in Labrador north of the Grenville Front (Emslie, 1980). The massif resisted the development of extensive penetrative fabrics and the associated pyroxene monzonites and rapakivi granites were protected adjacent to the massif. Such fabrics are better developed away from the massif, or are confined to relatively narrow shear zones that appear to entirely postdate crystallization of the rocks and may be much later (Grenvillian?). The massif thus forms the core of a large, regional, low-strain augen. There is little doubt that the igneous suite intruded amphibolite to granulite grade rocks that had already been deformed in one or more previous events, and that the grade of subsequent regional metamorphism was in the amphibolite facies.

The complex variations in attitudes of layered sections in the massif, coupled with widespread evidence of xenoliths and intrusive relations among units, suggest that intrusion was prolonged and involved both partly crystallized rock and largely liquid magma. Proportions of each were probably variable in time and space within the massif. The extent to which different magma pulses are represented, as opposed to successive intrusive events, cannot be assessed on field evidence alone. The common presence of well defined mineral layers is clear evidence that the massif cannot be regarded as a simple intrusion of plagioclase-rich crystal mush.

Xenoliths of country rock are rare in all of the major rock units associated with the massif. They are essentially absent from the massif itself and only a few small inclusions of basic to intermediate composition were noted within the pyroxene monzonite and rapakivi granite. The lack of country rock xenoliths suggests that magma stoping was not an important process of emplacement, and constitutes permissive evidence in support of diapiric intrusion.

According to Thomas (1974), much of the Atikonak River massif is undistinguished by significant positive or negative Bouguer anomalies; this seems to imply that either olivine-bearing rocks at depth are less abundant than they appear at the surface or that the massif is a relatively thin slab.

The Atikonak River massif is the northernmost of a number of large anorthositic massifs in this part of the Grenville Province (Figure 2). It is flanked to the southeast by gabbronorite (subunit 2d), which appears to correlate with the northern tip of a large positive gravity anomaly (Figure 5). This feature is in contrast to the generally low relief and negative anomalies of the anorthositic rocks in the region (Figure 5), and suggests that the whole of the gabbro to anorthositic gabbro lobe of Sharma and Franconi's (1975) Lac Fournier massif may be a separate metabasic plutonic suite that is unrelated to the anorthositic rocks. At present, the potential age of these metabasic rocks, and of the granitoid plutonic suite (subunits 5e and 5f) that intrudes them, also ranges between the Labradorian and Grenvillian orogenies.


66°00'W
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Kilometres
-400
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-500
-500
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-500
-600
-600
Atikonak River Massif
2e
?
2d
2?
-700
-800
Lac Fournier Massif
-700
-800
-200
-300
-400
-500
-600
-700
Romaine River Massif
-800
-700
-600
-600
-600
-500
50°50'N
66°00'W
50°50'N
63°00'W
Anorthositic Rocks
Metabasic Plutonic Rocks

Figure 5: *Gravity anomalies in the region of the Atikonak River massif showing a possible extension (2?) of the metabasic plutonic suite (2d and 2e) coincident with a strong positive anomaly [in part after Sharma & Franconi (1975), Thomas et al. (1984) and Nunn et al. (1984); gravity data from Geological Survey of Canada, 1986)].*

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ORDOVICIAN SEDIMENTARY STRATA OF THE PISTOLET BAY AND HARE BAY AREA, GREAT NORTHERN PENINSULA, NEWFOUNDLAND

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Newfoundland Mapping Section

ABSTRACT

Autochthonous Ordovician carbonate and siliciclastic rocks occur between Cambrian dolostones in the west and allochthonous sedimentary rocks of the Northwest Arm Formation in the eastern part of the map area. The Lower Ordovician St. George Group comprises four formations, the Watts Bight, Boat Harbour, Catoche and Aguathuna formations. Four lithologic members are delineated in the Catoche Formation within undolomitized parautochthonous strata. The members, in ascending order, are: 1) lower burrowed limestone, 2) middle mound, 3) upper burrowed limestone, and 4) white limestone. The Aguathuna Formation, which is mapped in this area for the first time, is thin and appears to rest disconformably upon the Catoche Formation. The Table Head Group comprises only the Table Point, Black Cove and Cape Cormorant formations. Fenestral limestones form an important member at the base of the Table Point Formation.

A number of erosional disconformities occur near the top of the St. George Group and the base of the Table Head Group. Growth faults breached the platform during the late Arenig, coinciding with regression on the platform and later early Llanvirn transgression. Shale-filled fissures, erosion and cementation at the top of the Table Point limestone, and abundance of Table Head-derived limestone breccias and possible olistoliths, suggest the area preserves the complex final stages of the Ordovician platform. The carbonates were succeeded by Middle Ordovician flysch, which flooded southwestward into the area.

Deformation began with the emplacement of Lower Ordovician mélange (Northwest Arm Formation) over the flysch basin and westward thrusting of parautochthonous limestones. This was followed by a later phase of compression in which a penetrative cleavage, westward-verging thrusts, northeast-trending, upright to overturned folds, and overthrusting, deformed the eastern half of the carbonate terrane, the flysch basin and the overlying mélange. The carbonate terrane was later extensively block faulted by northeast-, northwest-and west-trending high-angle faults.

Widespread sphalerite mineralization occurs in the Boat Harbour and Catoche formations within matrix breccias and secondary dolostones. Formation of cavern breccias and widespread dolomitization may have been partly controlled by the growth faulting that dissected the platform during late Arenig regression and karstification.

INTRODUCTION

Sedimentary rocks of Ordovician age underlie carbonate barrens, flat-lying peatbogs and the shoreline of Hare Bay and Pistolet Bay on the Great Northern Peninsula. Carbonate rocks of Early and Middle Ordovician age form a narrow south-trending belt of autochthonous and parautochthonous strata in the west. This belt is typified by extensive rock barrens, shallow peatbogs and tangled to open evergreen woodland. Topographic relief is generally low, but west of Hare Bay, limestone ridges rise up to 60 m above valleys of peatbog that occur just above sea level. To the east, the shore of Pistolet Bay and Hare Bay, and extensive lowlands between the bays, are underlain by folded, autochthonous, shaly flysch and some allochthonous sedimentary strata; the latter form the western leading edge of the Hare Bay Allochthon. Imbricated within the siliciclastics are thrust slices of Ordovician carbonate. Shallow boulder-strewn bogs and extensive peatbogs characterize the siliciclastic terrane.

The map area is reached via the Viking Highway (Route 73) from Deer Lake to St. Anthony. The highway crosses the map area just north of Hare Bay and provides outcrop and access to the southern part of the area. Farther south,inland areas can be reached on foot from the shores of Hare Bay; areas to the southwest are best reached by air. To the north of the Viking Highway, gravel roads to Cooks Harbour, Boat Harbour and Big Brook allow access to the northern area west of Pistolet Bay. Combined canoe and foot traverse along ponds and winter roads, and use of all-terrain vehicles over some rock barrens, provide access to the area between the gravel road to Big Brook and the Viking Highway.

Previous Work

Ordovician carbonate and clastic rocks of the area were first mentioned by Schuchert and Dunbar (1934) in their stratigraphy of western Newfoundland. Reconnaissance mapping of the Hare Bay area by Cooper (1937) provided the first geologic subdivision of rock units. Cooper also named some of the rock units, including the shaly flysch,which he called the Goose Tickle slate. Tuke (1968) later investigated the stratigraphy, paleontology, deformation and structural setting of the rocks mostly around Pistolet Bay. Tuke's work and the mapping of mining companies were incorporated in a recently published map and memoir by Bostock *et al.*, (1983); no

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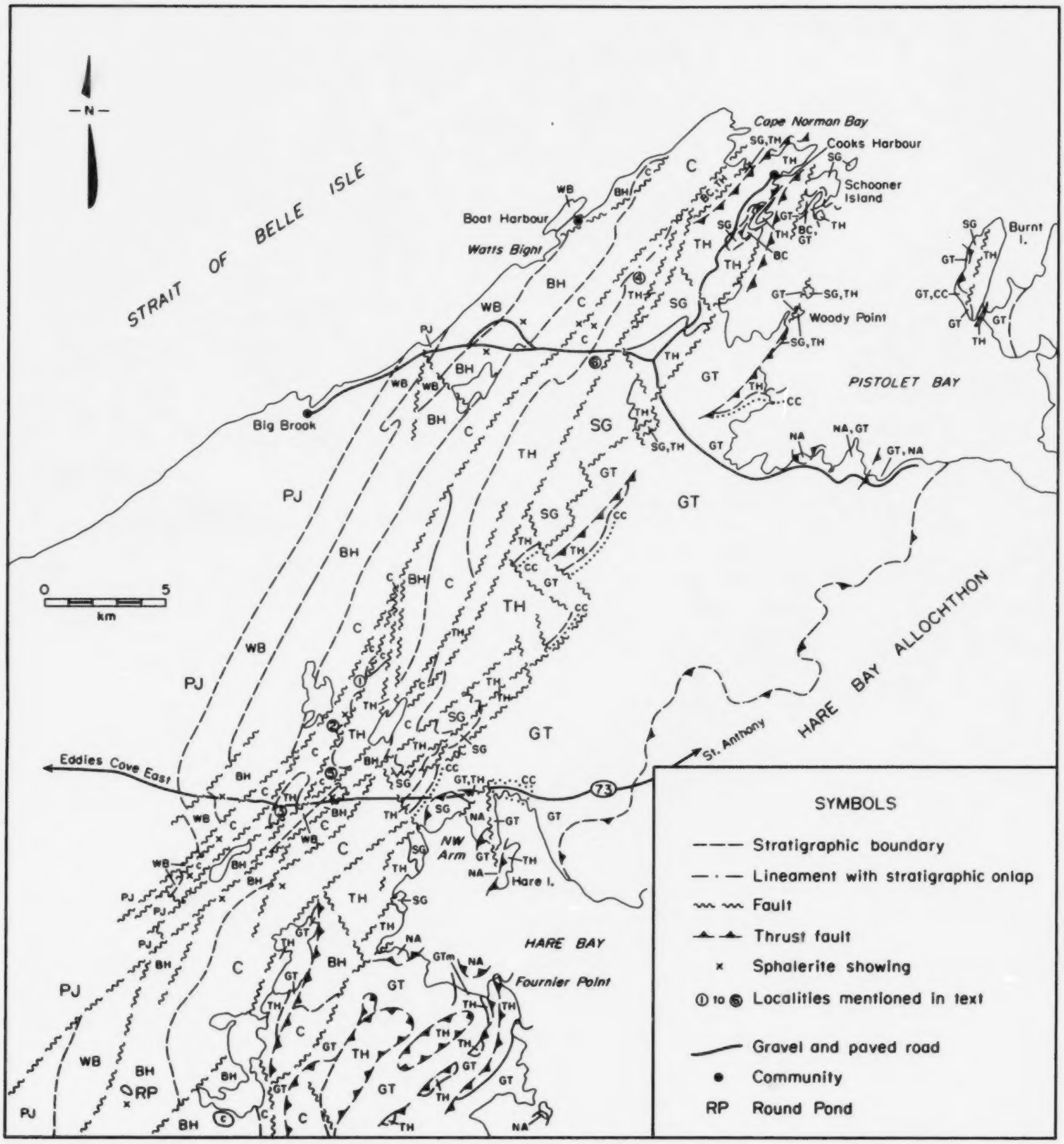
N
STRAIT OF BELLE ISLE
Cape Norman Bay
Cooks Harbour
Schooner Island
Boat Harbour
Watts Bight
Burnt I.
Woody Point
PISTOLET BAY
Big Brook
Eddies Cove East
St. Anthony
73
HARE BAY ALLOCHTHON
NW Arm
Hare I.
HARE BAY
Fournier Point
0
5
km
PJ
WB
BH
C
TH
SG
GT
CC
NA
BC
GTm
RP
SYMBOLS
Stratigraphic boundary
Lineament with stratigraphic onlap
Fault
Thrust fault
× Sphalerite showing
① to ⑤ Localities mentioned in text
Gravel and paved road
● Community
RP Round Pond

Figure 1: *Geological sketch map of the Pistolet Bay and Hare Bay areas.*

LEGEND

ALLOCHTHONOUS ROCKS

ORDOVICIAN

NA NORTHWEST ARM FORMATION (L. ORD): pyritiferous, green and black shale, gray and black bedded chert, gray limestone including limestone breccia, calcarenite, calcisiltite, thinly bedded ribbon limestone and shale, gray sandstone and locally thick, dark-gray, intraclastic gritty sandstone, and conglomerate.

AUTOCHTHONOUS ROCKS

MIDDLE ORDOVICIAN

GT GOOSE TICKLE FORMATION: dark-gray shale, green-gray sandstone, thinly bedded limestone, slump breccia, shale-pebble conglomerate.

Table Head Group

CC CAPE CORMORANT FORMATION: limestone breccia, calcarenite, and calcisltite.

TH UNDIVIDED TABLE HEAD GROUP: includes Table Point Formation of light-gray to dark-gray, fenestral to thickly bedded, fossiliferous limestone and minor dolostone, and limestone breccia; and Black Cove Formation of black, graptolitic, pyritiferous shale.

LOWER ORDOVICIAN

St. George Group

SG Undivided St. George Group

C CATOCHE FORMATION: undivided; gray limestone, burrowed, cryptalgal mounds, fossilferous; includes overlying thin Aguathuna Formation of yellow weathering dolostone with minor limestone.

BM BOAT HARBOUR FORMATION: interbedded dark to light-gray, dolomitic limestone and buff dolostone, cryptalgal limestone (dolomitization common throughout), widely preserved chert and matrix breccia bodies, especially at base.

WB WATTS BIGHT FORMATION: dark-gray to black, fine to medium grained crystalline dolostone, characterized by light-gray to cream mottling and large cryptalgal mounds.

CAMBRIAN

Port au Port Group

PJ PETIT JARDIN FORMATION: undivided yellow to buff weathering, pale-gray to blue-gray, microcrystalline to finely crystalline dolostone.

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systematic subdivision of the Ordovician carbonates was attempted in that study. Autochthonous Cambrian and Ordovician strata were subdivided in preliminary maps of the Big Brook (12P/9), Eddies Cove (12P/8) and Raleigh (2M/12) map areas by Knight *et al.* (1980) and Knight and Edwards (1978a,b).

The map area contains numerous small sphalerite showings and has been explored by several mining companies. The most extensive work was undertaken by Cominco (Cajka, 1969) who produced a geologic map of the carbonates from Cape Norman to south of Hare Bay. The Ordovician rocks were divided according to lithology, which included several varieties of limestone and dolostone. However, no lithostratigraphic subdivision was attempted. The work of Cominco highlighted mineralization in several areas and led to specific exploration by several companies over the next twenty years (Cominco, 1970; Phillips Management, 1975; Kerr Addison, 1976a,b,c,d,e; Shell Canada, 1975, 1976a,b,c,d,e,f,g; Dean, 1977; Noranda, 1978; John Leslie and Associates, 1980; U.S. Borax, 1980; Essex Minerals, 1981; Narex, 1983).

STRATIGRAPHY

Ordovician Carbonate Rocks

The stratigraphy of Ordovician carbonate strata has been defined in recent years by Knight and James (*in preparation*) and Klappa *et al.* (1980). This framework (Figures 1 and 2) is applied to the carbonates of the map area. The area, however, has a unique character such that several new lithological members have been mapped within the basic formational framework of the St. George (Knight and James, *in preparation*) and Table Head (Klappa *et al.*, 1980) groups.

St. George Group. The St. George Group comprises limestone, dolomitic limestone and syngenetic and secondary dolostone. It is approximately 395 m thick and includes the Watts Bight, Boat Harbour, Catoche and Aguathuna formations.

Watts Bight Formation

The Watts Bight Formation consists of a 90 m thick section of blocky to friable, tan-gray weathering, dark gray and black, fine and medium grained, crystalline dolostone. The dolostones have replaced dominantly subtidal, burrowed and cryptalgal limestone. Original textures are revealed by a characteristic light-gray to white fabric-selective mottling. Large stromatolite and thrombolite mounds, burrowed carbonate, cross-bedded grainstones and minor laminated dolostone occur. There are many cavities 1 to 10 cm in diameter within the formation, many of them partly filled by black and pinkish-buff, geopetal dolomite and dolomite mudstone. The formation has a sharp conformable contact with underlying, white, light-gray and gray, microcrystalline to finely crystalline dolostones of the Petit Jardin Formation.

Boat Harbour Formation

The Boat Harbour Formation, in contrast, comprises an approximately 120 m thick section of cyclically alternating limestone, dolomitic limestone and dolostone, and lies conformably upon the Watts Bight Formation. The basal unit consists of yellow weathering, thinly bedded, laminated and mottled, dark-gray to light gray, fine grained dolostones. Common within this unit, and locally straddling the basal contact, are breccia pods containing a dolostone-chert matrix. The breccias are up to tens of metres in size, consisting of angular fragments (approximately 1 cm across) of the host rock dolostones set in a fine grained matrix of siliceous dolomite. Fracture breccias and veins, cemented by white dolomite spar, commonly occur in the dolostones above and around the matrix breccia.

Silicification of the rocks in the basal interval is widespread. Chert has selectively replaced stromatolites, cryptalgal laminite, mudcracked laminated carbonate, and clasts of rip-up intraformational conglomerate. Lumps of white chert and concentrically layered chert concretions also occur. Lithoclasts of the cherts are incorporated in the matrix breccias suggesting it has either an early syndepositional or postdepositional origin. Poor exposure of the contact between the breccias and the host rocks makes interpretation of the breccias difficult. In some coastal and quarry exposures, however, the breccias involve thrombolitic dolostone beds of the underlying Watts Bight Formation and are commonly accompanied by a system of fractures. Dolostone beds, as they enter the breccia toward its base, have been warped downward, suggesting material was removed from underneath; the beds are broken in the breccia. Within the breccia proper, large blocks up to 1 m across have a vague imbricated stacking above a finer breccia at the base. There is a crude lithological stratigraphy of the blocks within the breccia at Boat Head. The lower parts of the breccia have a matrix of smaller dolomite - chert clasts and sand. However, the top of the

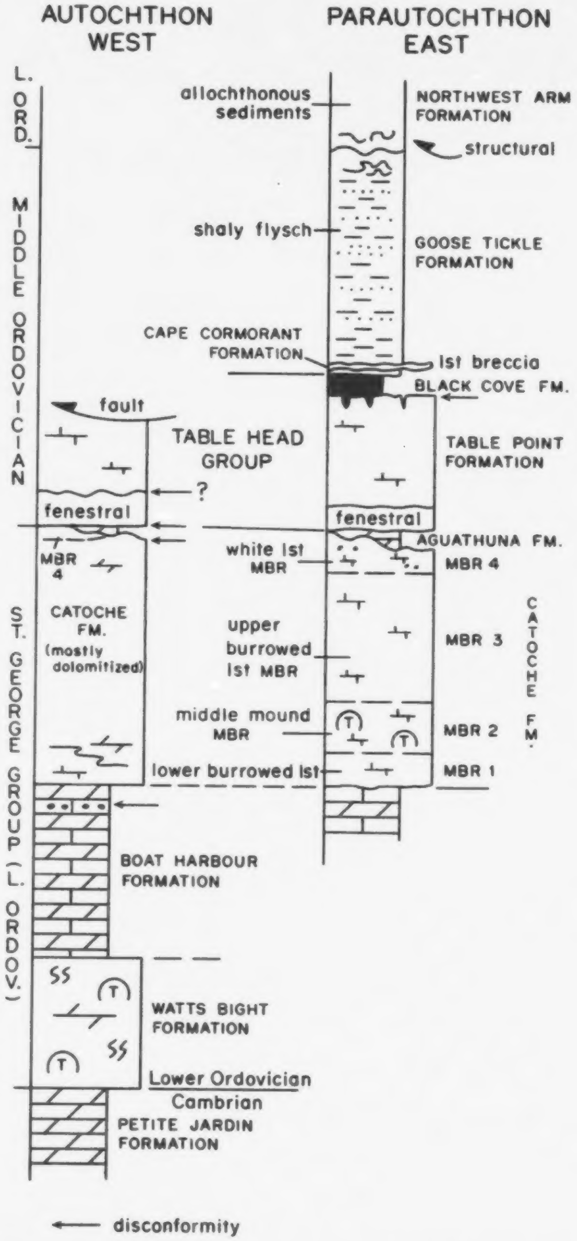
AUTOCHTHON
WEST
PARAUTOCHTHON
EAST
L. ORD.
MIDDLE ORDOVICIAN
allochthonous sediments
NORTHWEST ARM FORMATION
structural
shaly flysch
GOOSE TICKLE FORMATION
CAPE CORMORANT FORMATION
1st breccia
BLACK COVE FM.
fault
TABLE HEAD GROUP
?
TABLE POINT FORMATION
fenestral
fenestral
AGUATHUNA FM.
white lst MBR
MBR 4
MBR 4
CATOCHE FM. (mostly dolomitized)
upper burrowed lst MBR
MBR 3
CATOCHE FM.
middle mound MBR
MBR 2
lower burrowed lst
MBR 1
ST. GEORGE GROUP (L. ORDOV.)
BOAT HARBOUR FORMATION
WATTS BIGHT FORMATION
Lower Ordovician
Cambrian
PETITE JARDIN FORMATION
disconformity

Figure 2: *Stratigraphy of Ordovician rocks of the Pistolet Bay-Hare Bay area.*

breccia at Boat Head is spar cemented beneath fractured but bedded dolostones. In quarry exposures on the Viking Highway, the matrices of breccia pockets in Watts Bight dolomites are partially replaced by coarse grained dolomite. Pyrite and less commonly sphalerite and galena also occur in the breccias.

Above the basal dolostone-breccia interval, the formation consists of metre thick sequences of burrowed, fossiliferous, dark-gray limestone, wavy, flaser, and thinly bedded dolomitic limestone and mudcracked dololaminite and laminated dolomitic limestone. Stromatolitic and thrombolitic limestone occur in some of the sequences, which are typical of shallow peritidal settings, especially muddy tidal flats.

Approximately 12 m from the top of the Boat Harbour Formation, there is a disconformity. It is characterized by a thin pebble bed of white and dark-gray chert pebbles in light-gray dolostone at Boat Harbour and on the gravel road to Big Brook. In frost-shattered outcrops north and south of the Viking Highway, it is characterized by conglomerate and pebbly dolostone. The conglomerates are up to 25 cm thick, consist of pebbles 1 to 3 cm across, angular, white cauliflower and gray chert pebbles mixed with subrounded to rounded, massive to laminated, dolostone pebbles. Crude planar stratification and grading occur in the conglomerate. The variable thickness of the conglomerate suggests it lies above an erosion surface, although this has not been confirmed.

Above the disconformity, the Boat Harbour Formation continues to exhibit cyclic sequences of very fossiliferous, grainy limestone, burrowed limestone, and flaser bedded, laminated, mudcracked limestone and dolostone. Rare mound beds of cryptalgal thrombolite occur locally.

Dolomitization that is both pervasive and bed selective replaces limestone, resulting in mottled dolostone, vuggy dolomite pseudobreccia and salt and pepper dolomites.

Catoche Formation

The Catoche Formation is a 170 m thick succession of subtidal dark-gray and white limestone. The carbonates, in undolomitized parautochthonous eastern strata, consist of burrowed fossil-rich limestones, sponge-thrombolite mounds, grainy limestones, white peloidal grainstones, and fenestral limestones. In autochthonous western sections, near Cape Norman and southward to the Viking Highway, this same section is extensively dolomitized to dark-gray, massive, crystalline dolostone and pseudobreccia.

Four lithologic members are divisible in the formation on Schooner Island: 1) a lower burrowed limestone member, 2) a middle mound member, 3) an upper burrowed limestone member, and 4) a white limestone member. The lower burrowed limestone member is 18 m thick and consists of gray, unevenly thin bedded limestones. The limestones consist of burrowed fossiliferous mudstone containing many lenses and thin beds of intraclastic and bioclastic grainstone and rudstone. Some cryptalgal mound beds also occur. The overlying middle mound member is 34 m thick and consists of very large, massive mound complexes composed of cryptalgal thrombolites and scattered sponges. Host to numerous large shelly organisms and possessing evidence of marine cementation, the high-energy mound complexes are surrounded by grainstone fringes and channel fills. Above the middle mound member, dark-gray, massively bedded, burrowed limestones begin the upper burrowed limestone member. These rock types continue through the 105 m thickness of the upper burrowed limestone member, intercalated with cross-laminated and wavy thin bedded grainstones. Some thrombolite mound beds occur sporadically. The limestones have considerably less fossils than the lower member although silicified cephalopods, gastropods and rostroconchs do occur.

The Cathoche Formation is capped by a 13 to 16m thick member of white limestone. The member includes stylolitic, peloidal grainstones, massive, mottled, thrombolitic boundstones and beds of fenestral white limestone. Large shelly fossils occur sporadically in the member and include trilobites suggestive of Ross-Hintze trilobite Zones H to I (Boyce, *this volume*). This member is well exposed on Schooner Island and Burnt Island and in folded sections along the shores of Hare Bay. Roadside outcrops of the member also occur along the Viking Highway near the new St. Anthony airport and at the airport itself. The member outcrops discontinuously in autochthonous, gently dipping strata in the western part of the map area. In some instances, it appears to be crosscut erosively by the overlying Aguathuna Formation, e.g., localities 1, 2 and 3 on Figure 1. At locality 5 (Figure 1), there is no evidence that the member occurs beneath the Aguathuna Formation, which rests upon dark-gray, secondary dolostones typical of those that replace the upper burrowed limestone member. Honey-colored weathering, light-gray pseudobreccias and secondary dolostones replace the white limestone member, making distinction between members possible where the succession is extensively dolomitized.

Aguathuna Formation

The Aguathuna Formation is mapped for the first time in the area. In sections on Schooner Island and the shoreline of Hare Bay, it is between 7 and 16 m thickness. Rocks typical of the formation are absent on Burnt Island, where an erosional disconformity separates overlying rocks assigned to the Table Head Group from the white limestone member of the Catoche Formation. A finely laminated dolostone and dolomitic limestone bed, 60 to 210 cm thick, overlies the erosional surface and may be the only strata that belong to the Aguathuna Formation (see later discussion of disconformity). However, the laminite also closely resembles basal beds in the Table Point Formation elsewhere in the area.

The Aguathuna Formation on Schooner Island, Hare Bay, and in some sections on the southwest side of Pistolet Bay, predominantly consist of 1.5 to 7.5 m thick units of medium bedded, pale-gray, microcrystalline dolostone, intercalated with two or three beds, 40 to 100 cm thick, of pale-gray to white limestone. The limestones are cryptalgal laminites and stromatolites composed of laterally linked hemispheroids. Burrow-mottled limestone locally occurs near the base of the formation where it is intercalated with the dolostones. Sedimentary structures in the dolostones include planar to undulose, thin stratification and lamination, cross-lamination, shallow scours, desiccation cracks, disrupted lamination, and white chert cauliflower nodules. These structures and rock types support a restricted intertidal-supratidal origin for the formation.

Table Head Group. Limestones of the Table Point Formation, black shales of the Black Cove Formation and pebbly mudstone and calcarenite of the Cape Cormorant Formation define the Table Head Group in the map area. No Table Cove Formation (see Klappa *et al.*, 1980) occurs.

Table Point Formation

The Table Point Formation is about 80 m thick and consists of dark-gray to light-gray limestone, minor dolomitic limestone and a variety of dolostones. The widest range of rock types occurs in the first 25 m of the formation where three lithological associations are defined. Directly overlying the Aguathuna Formation, rock types range from basal limestone-dolostone conglomerates, through nodular, thin bedded, argillaceous, fossiliferous, limestones, to dolomitic limestones and dololaminites. The dolomitic limestones and dololaminates are flaser bedded, cross-laminated, laminated and mudcracked. This association, which can be up to 2.2 m thick, is best seen in the area of Schooner Island and southwestward from Cooks Harbour to the new St. Anthony airport. The basal conglomerate on Schooner Island is composed of large platy dolostone clasts up to 12 by 2 cm in size, mixed with smaller pebble and sand-sized dolostone grains and pebbles of white quartz. The Aguathuna dolostones are locally brecciated and penetrated by fractures filled with sandy dolomitic limestone for up to 20 cm below the Table Point Formation. Conglomerate beds higher in the lithological association fill channels that cut into nodular thin bedded limestones. Thin lenses of laminated lime mudstone occur in the conglomerates. Conglomerates are absent in the Hare Bay sections where laminated and flaser bedded dolostone and dolomitic limestones lie sharply upon the Aguathuna Formation.

The second lithological association overlies the thin basal association on Schooner Island. It also occurs in the core of a tight anticline just north of the fish plant at Cooks Harbour, and outcrops at the new St. Anthony airport. It consists of thick units of gray, nodular, thin bedded, argillaceous limestone, containing intercalated beds of skeletal packstone, grainstone and coquina limestone, parted dolomitic limestone and beds of mixed grainy and parted limestone. The coquinas are rich in brachiopods. At the top of the sequence, a bafflestone bed, 1.2 m thick, contains stick sponges in a wackestone matrix.

The third lithological association is delineated on Burnt Island and in the most westward outcrops of the Table Point Formation near the Big Brook road (locality 6, Figure 1), and in outliers north of the Viking Highway (localities 3 and 5, Figure 1). This association consists of thick beds of nodular, thin bedded, dark-gray limestone and of light-gray, fine grained limestone. Typically, the fine grained, light-gray limestone beds consist of fossiliferous limestones rich in large gastropods and cephalopods that are replaced by calcite spar. Large burrows and large 'stromatactoid' cavities are also spar cemented. The tops of beds are rich in layers of fine tubular and laminar fenestra, and are faintly laminated. They commonly contain ostracodes, and mudcracks occur at the top of some beds. Oncolites, coated grains, intraclasts and bioclasts occur in grainy layers in the nodular limestones.

An impressive, irregular, downcutting erosion surface (Figure 3) occurs in the fenestral limestone facies in a roadcut and quarry on the Viking Highway (locality 3, Figure 1). Locally, conglomerate lags occur at the base of the channel and limestones are locally dolomitized to yellow weathering, microcrystalline dolostone beneath the erosion surface.

The remaining 50 m of the Table Point Formation consist of dark blue-gray, seamy, argillaceous limestones. They characteristically consist of thick beds of burrowed, fossiliferous wackestone-packstone. Rare beds of peloidal grainstone and chert layers also occur. Where the top of the formation escaped erosion, the limestone consists of crinoid-trilobite-brachiopod-rich grainstone and packstone. These grainy beds are present on Schooner Island and in thrust slices of the formation at Shallow Bay, Pistolet Bay. They are missing and believed eroded in outcrops on the east side of Woody Point, on Burnt Island, and on Hare Island, Hare Bay. In each case, the top of the limestone is cemented by a carbonate-silica crust, 2 to 3 cm thick. On the south side of Burnt Island, the top is hummocky, and cut by fractures and faults with small displacements. The surface, including the fractures and fault planes, is impregnated by the crust. The top of the limestone is everywhere overlain by black shales assigned to the Black Cove Formation.

Black Cove Formation

The Black Cove Formation is 7 to 8 m thick. It consists of finely laminated, pyritiferous, graptolitic, black shale. Pyritic laminations and light-gray concretionary limestones occur in the formation. The Black Cove Formation lies sharply upon the Table Point Formation, and in some outcrops it infills long narrow fissures that penetrate tens of centimetres down into the underlying Table Point Formation. The shale also overlies the eroded top of the Table Point Formation at Burnt Island, although here it is only 1.8 m thick.

In Cailloux Bay and Vaches Point, Cape Norman Bay, the black shales are intercalated stratigraphically with three units of matrix-poor limestone breccia. The shales form units 4 to 14 m thick and the limestone breccia units are 5 to 19 m thick, in a section at least 60 m thick. The breccias are composed of black wackestone fragments, 1 to 10 cm across, of the Table Point Formation, as well as fragments of white sponge, white crinoid-trilobite grainstone (probably from the top of the Table Point Formation), platy lime mudstone lithoclasts and irregular shale rip-ups. The main lithoclasts fit neatly together with only a hairline of shale matrix in between. Similar limestone breccias overlain by shale of the Black Cove Formation occur in structurally complicated areas of Pistolet Bay and Hare Bay. In none of these instances are the shales repeatedly intercalated with limestone breccias as at Cape Norman Bay. At Cape Norman Bay, however, contacts between breccias and overlying shales are not exposed and it is impossible to know if the two rock types are structurally intercalated. A number of lines of evidence, however, suggest that the upper contacts are stratigraphic. Firstly, the thicknesses of the breccias are markedly different. Secondly, the abundance of non-wackestone clasts differs from breccia to breccia. These two properties suggest that the breccias are separate units. In addition, where thrust contacts have been mapped in the area, limestones are always thrust over Black Cove black shales, and not vice versa. However, basal contacts of the limestone breccias with the shales at Cape Norman Bay are stratigraphic.

An unexposed area conceals approximately 35 m of strata above the last breccia. The covered interval ends at Vaches Point where shales and thin bedded sandstones and limestones typical of the base of the Goose Tickle Formation are overlain along a structurally modified contact by a further limestone breccia several metres thick. Unlike the lower breccias, it contains blocks of Table Point limestone up to several metres across within the finer lime breccia. The breccia appears to pass eastward beneath unbrecciated Table Point limestone (Sheila Stenzel, personal communication, 1985). These enigmatic limestone breccias are not included here with limestone pebbly mudstones and calcarenites that are assigned to the Cape Cormorant Formation.

Cape Cormorant Formation

The Cape Cormorant Formation is a thin, distinct unit composed of matrix-supported pebbly mudstone at the base, and granular to very fine grained calcarenites and calcisiltites at the top. The formation is variably developed and consists only of the calcarenite bed in some sections, e.g., Schooner Island and parts of Burnt Island. In roadcuts on the Viking Highway and coastal exposures near Northern Arm, Hare Bay, the pebbly mudstone is possibly up to 6 m thick. In thrust slices on the east side of Woody Point, Pistolet Bay, it is 0.95 to 2 m thick.

The pebbly mudstone consists of irregular, knobbly lithoclasts 1 to 6 cm across, of Table Point limestone and 10 cm to 1 m wide blocks of Table Point limestone, Black Cove shale, platy lime mudstone, thin bedded limestone, grainstone, and dolomitic calcareous siltstone and sandstone, all set in a shaly matrix. Sandstone rip-ups from the underlying beds are incorporated in the pebbly mudstone at roadcut exposures on the Viking Highway. In Pistolet Bay, the bed has a well developed stylolitic cleavage which surrounds the lithoclasts; some platy clasts are rotated into the plane of the cleavage.

A bed of graded calcarenite up to 75 cm thick lies above the pebbly mudstone. It is the most widespread unit of the formation and is locally only 30 cm thick. A normally graded bed, it is composed of grit or very coarse grained calcarenite at the base and very fine grained lime sand at the top. The bed consists of a massive basal interval, overlain by laminated, and cross-laminated intervals, both of which are commonly convoluted. The top of the Cape Cormorant Formation is marked by a 30 to 65 cm thick bed of light-gray calcisiltite. Internally, the bed is highly convoluted although originally it may have been cross-laminated.

Klappa *et al.* (1980) defined the Cape Cormorant Formation as a sequence of dark-gray to black calcareous shales and green siltstones, with interbedded calciturbidites and limestone breccia-conglomerates that lay between Black Cove shales and green sandstones similar to those of the Goose Tickle Formation. In the map area, sandstones and shales lithologically similar to those of the Goose Tickle Formation lie between the Black Cove shale and the base of the Cape Cormorant limestone breccias and calcarenites. At North Arm, Hare Bay, there are at least 5 m of sandstones beneath the Cape Cormorant Formation and in the Pistolet Bay area 50 to 100 cm of Goose Tickle type siliciclastics are sandwiched between the Cape Cormorant Formation and the Black Cove shales. Positional problems such as this, together with the absence of the Table Cove Formation in this area and the clearly disconformable top to the Table Point limestones, suggest that the Black Cove and Cape Cormorant formations would be best considered outside the Table Head Group.

Ordovician Siliciclastic Rocks

This grouping of rock units includes autochthonous Middle Ordovician shaly-sandy flysch of the Goose Tickle Formation and allochthonous melange-like strata of the Lower Ordovician Northern Arm Formation.

Goose Tickle Formation

The Goose Tickle Formation is a highly folded succession of gray to black, locally graptolitic, shales, sandstones and lesser thin calcareous beds. The sandstone beds are mostly 5 to 20 cm thick and fine to very fine grained. They are typified by laminated B, and cross-laminated and ripple drift C Bouma divisions. Thin, very coarse to coarse grained sandstones occur at the base of some beds. Convolution and overturning of cross-lamination is common with structures facing to the south. Fluted and loaded bases are also common. Paleoflow directions are consistently directed to the south.

The formation is finer grained in the Hare Bay area, where it has a strong slaty cleavage. Several metre-thick units of intraformational breccia, composed of deformed lithoclasts of Goose Tickle mudstone and fine grained sandstone, are interbedded stratigraphically high in the formation in the vicinity of Goose Tickle, Hare Bay. Basal contacts are transgressive and erosive. However, upper contacts are not sufficiently exposed to indicate if the breccia formed as discrete episodes of slumping or as intraformational slides related to emplacement of the Taconic sedimentary rocks of the Hare Bay Allochthon.

Immediately below the allochthonous Northwest Arm Formation, the Goose Tickle Formation is strongly flattened. In this flattened zone, which presumably involves only the youngest beds of the formation, there are some intraclastic grits and conglomerates. They range from a few centimetres to 25 cm thick, are interbedded with shales and thin sandstones, and contain green and black shale intraclasts. These intraclasts were interpreted by Williams and Smyth (*in* Bostock *et al.*, 1983), to have been derived by erosion of Northwest Arm Formation shales.

The Northwest Arm Formation is a mélange-like deposit composed of interlayered black and green, pyritiferous shale containing suspended dismembered beds and sequences of various other rock types. These include gray, green and black, bedded cherts, light-gray ribbon limestones and shales, granular to sandy calcarenites displaying Bouma sequences, thin, cross-laminated and laminated, calcareous siltstones and fine sandstones, and thick green-gray gritty sandstones. Red siltstone blocks occur in the formation on the west side of Hare Island.

EVOLUTION OF ORDOVICIAN PLATFORM

Disconformities, Growth Faults and Breccias

Discussion. Variations in limestone successions laid down on carbonate platforms are the response to fluctuations of relative sea level rise and fall (James, 1984). During prolonged periods of relative sea level rise, shallow-shelf seas transgress onto the platform and lead to widespread deposition of dominantly subtidal carbonate. During relative sea level fall, the shallow seas are overwhelmed by production of carbonate sediment and peritidal sediments are widely deposited. Regional subaerial exposure leading to karstification of the platform carbonates may mark the end of this fall in sea level.

In western Newfoundland, the St. George Group consists of two megacycles that contain a history of subtidal to peritidal sedimentation and eventual subaerial exposure (Knight, 1980, 1985; Knight and James, *in preparation*). The two megacycles involve Tremadoc and Arenig strata. The older disconformity, represented by the Boat Harbour 'pebble bed', terminates the Tremadoc cycle. A relatively obscure feature, it is known to coincide with the absence of Ross-Hintze trilobite Zone G (Boyce, 1983) and faunal changes in both conodonts (Stouge, 1982) and trilobites (Boyce, 1983).

Evidence for the closing history of the later Arenig cycle is more spectacular. Previously, evidence for an interval of subaerial exposure at the top of the St. George Group in the map area was confined to knowledge of an erosion surface between the St. George and Table Head Groups on Burnt Island (Cumming, *in* Bostock *et al.*, 1983). However, there is new evidence in the map area of not only multiple breaks during this period, but also of active faulting affecting the Ordovician platform. Three erosional surfaces occur:

1) *at the base of the Aguathuna Formation.* The evidence for this break includes: a) erosion of the white limestone member of the Catoche Formation below the Aguathuna Formation dolostone at localities 1,2,3, and 5, Figure 1; b) dolostone-filled fractures and breccias in the underlying white limestones in sections at Hare Bay and the east side of Woody Point, Pistolet Bay. Similar fractures and porosity occur in the white limestones beneath the disconformity on Burnt Island. A fracture cutting third member limestones of the Catoche Formation is cemented by chert in the section in Hare Bay; c) onlap of a northeast-trending lineament by gently eastward-dipping Aguathuna and Table Point formations at locality 4, Figure 1. Brecciated, cavernous and silicified, dark-gray dolostones that replace limestones of the Catoche Formation lie against the lineament to the northwest. The Catoche Formation strata are locally folded at the southwest end of the lineament, where they appear to be unconformably overlain by the Aguathuna Formation.

A number of lines of evidence suggest the lineament is a late Arenig feature rather than a later fault. Firstly, later faults that cut Ordovician carbonates are usually typified by closely spaced joints that parallel the fault plane. This feature does not occur in strata adjacent to the lineament. Also, strata of the Aguathuna and Table Head formations show no sign of buckling, as might be expected if they were affected by later faulting. Secondly, the lineament cannot be traced southwestward into a succession that is apparently conformable through the Catoche Formation into the Table Head Group. To the northeast, the lineament is cut out by later faults that have a north to northeast trend. Lastly, at one locality, a tongue of frost-shattered syngenetic dolostone, similar to dolostones of the Aguathuna and basal Table Point formations, oversteps the lineament onto the Catoche dolostones. Cavity porosity in the Catoche dolostone at the margins of the tongue are infilled by the younger dolostone. This suggests that the frost-shattered dolostones are essentially in place (not the product of Quaternary marine or glacial transportation) and that they infilled a shallow trough in the Catoche dolostones. The onlap implies subaerial exposure of the Catoche Formation and the lineament.

2) *at the base of the Table Point Formation.* Evidence for a disconformity at this contact is suggested by: a) basal conglomerates composed of dolostone pebbles at the base of the Table Point Formation on Schooner Island and south of Cooks Harbour. No conglomerate occurs in the Hare Bay sections, where Aguathuna dolostones are abruptly overlain by laminated limestones of the Table Point formation; b) limestone and rubble-filled fractures that penetrate as much as 20 cm down into the top of the Aguathuna Formation at several localities; c) the presence of a marked erosion surface and the absence of Aguathuna dolostone at Burnt Island. Here the Table Point Formation lies directly upon white limestone of the Catoche Formation. Secondary porosity and narrow fissures, both filled by dolomite mudstone penetrate the white limestones for several metres below the disconformity. The disconformity is overlain by laminated dolostone and limestone assigned to the Table Point Formation.

3) *within the fenestral limestone association of the basal Table Point Formation.* A well exposed surface of erosion (illustrated in Figure 3) with relief of 2 to 3 m occurs in a roadcut and quarry on the Viking Highway (locality 3, Figure 1). Macrofossils above and below the surface are the same (Boyce, personal communication, 1985), suggesting no significant length of geologic time is represented. However, pebbles of limestone and dolostone with spar-cemented fenestra occur in the overlying limestones, suggesting that the underlying carbonates were already lithified. Beds below the erosion surface were also slightly tilted.

Bodies of matrix and spar breccia occur regionally in the basal part of the Boat Harbour Formation. They also straddle the contact between the Watts Bight and Boat Harbour formation.

Interpretation. Two distinct episodes of subaerial exposure affected the Ordovician platform. Both terminated a time of regression on the platform when relative sea level fell and shallow-water peritidal carbonates were exposed and subjected to diagenesis, dissolution and erosion (Knight and

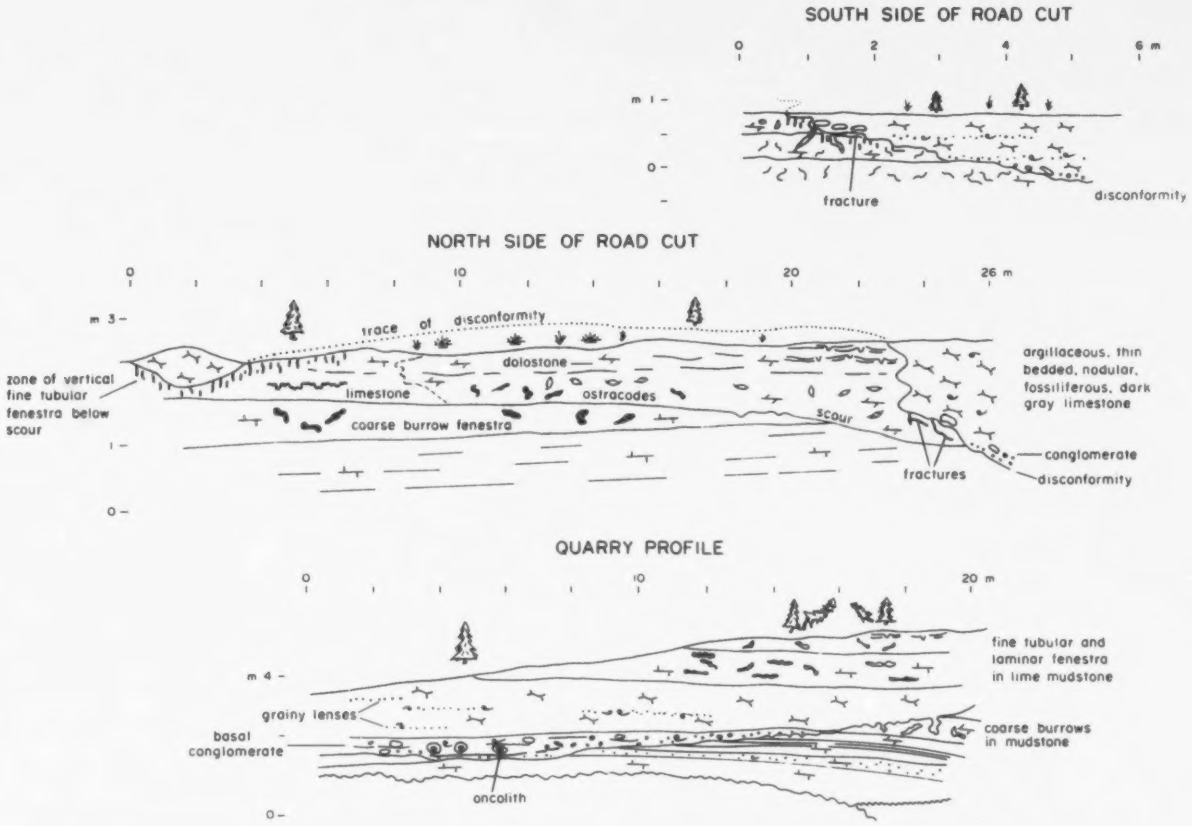
SOUTH SIDE OF ROAD CUT
0
2
4
6 m
m 1
0
fracture
disconformity
NORTH SIDE OF ROAD CUT
0
10
20
26 m
m 3
1
0
trace of disconformity
dolostone
limestone
ostracodes
coarse burrow fenestra
scour
zone of vertical fine tubular fenestra below scour
argillaceous, thin bedded, nodular, fossiliferous, dark gray limestone
conglomerate
disconformity
fractures
QUARRY PROFILE
0
10
20 m
m 4
0
fine tubular and laminar fenestra in lime mudstone
grainy lenses
basal conglomerate
coarse burrows in mudstone
oncolith

Figure 3: *Field sketches of disconformity surface in basal strata of the Table Head Group, Viking Highway (localtiy 3, Figure 1).*

James, *in preparation*). There is, however, a marked contrast between the Tremadoc and later Arenig event. The older event developed upon a relatively stable platform such that thickness and patterns of lithofacies above the Boat Harbour disconformity are relatively consistent throughout western Newfoundland. Physical evidence of the karst is limited to thin pebble lags and chert conglomerates associated with dolomitization, silicification and dissolution. The break is supported by faunal evidence.

The younger event is clearly much more complex. At the end of the Arenig, western Newfoundland was under tectonic stress, and faults broke through the platformal cover (see Knight, 1985, page 84; Knight and Boyce, 1984). The onlap of the lineament by both the Aguathuna and Table Point formations suggest that the faults penetrated the carbonates toward the end of the Arenig, after white limestones of the Catoche Formation containing Ross-Hintze Zone H to I trilobites were deposited. Because the lineament follows the trend of and lies between braids of the Ten Mile Lake Fault system, it is interesting to speculate that it may preserve evidence of Arenig movement upon the fault. Outliers of the Table Head and Aguathuna formations near the Viking Highway are preserved within a narrow zone of faults that are part of the Ten Mile Lake Fault system. Unconformable relationships of these rock units mapped in this fault zone may also reflect Arenig instability above the Ten Mile Lake Fault. On a regional scale, the faulting uplifted the Catoche carbonates- the subsequent erosion may be reflected in the unconformities on Burnt Island and locally in the Ten Mile Lake Fault system. Widely developed, brittle rock fractures and secondary solution porosity was later filled by Aguathuna dolostone. Dolomitization of extensive areas of the Catoche Formation to the west of the Ten Mile Lake Fault system occurred during this period of uplift. This is supported by the tongue of younger dolostones that oversteps both the lineament and Catoche Formation dolostones (locality 4, Figure 1), indicating subaerial exposure of the dolostones.

The marine waters that gently flooded this uneven platform surface were (or became) saline. Dolostones and laminated cryptalgal limestones of the Aguathuna Formation were deposited in tidal flats and possibly saline ponds and lagoons that merged about topographic islands.

A marked lithological change between the Aguathuna and Table Point formations, and brittle fracturing and erosion of the Aguathuna dolostones, suggests an erosional disconformity at the upper contact of the St. George Group. Of unknown magnitude, this event was followed by Middle Ordovician transgression. Fenestral limestones interbedded with fossiliferous burrowed limestone suggest prograding peritidal

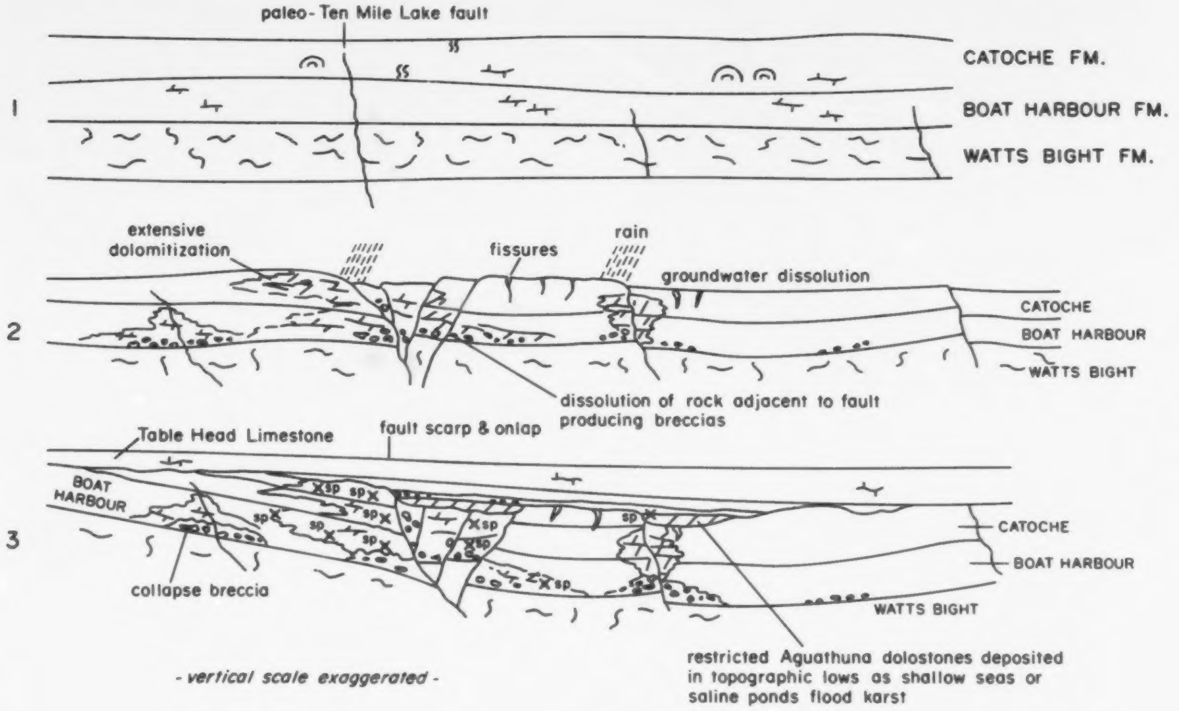
paleo-Ten Mile Lake fault
1
CATOCHE FM.
BOAT HARBOUR FM.
WATTS BIGHT FM.
extensive dolomitization
fissures
rain
groundwater dissolution
2
CATOCHE
BOAT HARBOUR
WATTS BIGHT
dissolution of rock adjacent to fault producing breccias
Table Head Limestone
fault scarp & onlap
BOAT HARBOUR
3
CATOCHE
BOAT HARBOUR
collapse breccia
WATTS BIGHT
restricted Aguathuna dolostones deposited in topographic lows as shallow seas or saline ponds flood karst
- vertical scale exaggerated -

Figure 4: *A simplified model of Ordovician platform history in the Pistolet Bay-Hare Bay area.*

1. *Buildup of stable platform throughout the Early Ordovician.*
2. *Late Arenig faulting coinciding with regional regression and subaerial exposure of the platform.*
3. *Erosion and karstification, followed by deposition of restricted lithofacies in lows on karst surface before later widespread Middle-Ordovician transgression. The platform was block faulted during Appalacian orogenesis with Ten Mile Lake Fault widely penetrating the platform in a system of new and reactivated splays.*

sedimentation accompanied by rapid lithification and freshwater diagenesis and cementation. This erosional surface suggests an interval of subaerial exposure during the early Llanvirn transgression. Tilting of beds prior to erosion indicates that some tectonism affected the platform during this interval.

The matrix and spar breccias that are discordant to bedding and are regionally associated with the lower strata of the Boat Harbour Formation are probably cavern breccias. Large open spaces created by dissolution were filled by overhead and marginal collapse. A crude stratigraphy of blocks, upward increase in block size in some breccias, and a pebble to silt size dolomite-chert matrix at the bottom of the breccias support the idea of caverns. Open spaces that remained at the top of the breccias, and in fractures that opened in overlying dolostones as they settled onto the breccias, were cemented by white baroque dolomite.

The primary control of these breccias is still unresolved. There is no evidence that the St. George Group contained significant bedded evaporites. Evaporitic cherts do occur and the silicification of algal mats in the basal Boat Harbour Formation may possibly reflect an evaporitic sabhka as seen in similar Ordovician ribbon cherts of the Aleman Formation, southwestern New Mexico (Geeslin and Chafetz, 1982). In other areas of the Northern Peninsula, it is dolomitized limestone beds which pass laterally into the matrix breccias (Knight, *in preparation*).

Located approximately 100 m stratigraphy below the Boat Harbour 'pebble bed', the cavern breccia and sediment-filled secondary porosity in the underlying Watts Bight Formation may be related to the episode of subaerial exposure that marked the close of the Tremadocian history of the platform. An alternative explanation would relate the breccias to the later Arenig episode of faulting and subaerial exposure. Block faulting of the platform during the Arenig event may have provided structural permeability for the movement of groundwaters and other fluids during and after the episode of subaerial exposure. In the map area, matrix breccias, extensive areas of dolomitization and minor metallic mineralization occur close to faults, especially the Ten Mile Lake Fault system (Figure 4), indicating fluid migration. The Boat Harbour matrix breccias are spatially related to major faults in other areas of the Northern Peninsula (Knight, 1985).

History of Platform Collapse

Tuke (1966), observing the sharp contact of Black Cove shale (he placed it in the Goose Tickle Formation) upon Table Point limestones, and the shale-filled fissure beneath this contact, suggested a disconformity at this boundary. The absence of the Table Cove Formation (Klappa *et al.*, 1980) between the limestone and the shale supports this idea. In addition, widespread evidence of deformation and erosion of the Table Point limestone and the early submarine(?) cementation of the eroded top of the limestone suggest a complex end to platform development.

In the siliciclastic sequence, the Black Cove shale is overlain by Goose Tickle Formation flysch in the Schooner Island section; the top of the Table Point Formation is a bioclastic grainstone-packstone. In other sections, the shales are interbedded with limestone breccias derived from Table Point limestone. Elsewhere, a thin unit of limestone, pebbly mudstone and lime turbidite overlie the black shale and are intercalated in the basal beds of the Goose Tickle Formation. The top of the Table Point limestone is generally cemented and/or eroded beneath the pebbly mudstone.

A sequence of events can be tentatively suggested based upon the above features. The last deposits of the Table Point Formation appear to consist of bioclastic grainstones and packstones. Limestone sedimentation ceased and the later development of fissures, as well as retention of the nodular form of limestone clasts in overlying breccias, suggests the Table Point Formation was at least partly lithified during an interval of nondeposition. The absence of Table Cove Formation suggests a slope did not develop in this area, the platform rapidly collapsed, and the shales were deposited on the drowned shelf. Tectonism probably created the fissures prior to deposition of the black shales in a basin or basins of restricted circulation (Klappa *et al.*, 1980).

In some areas of the basin, Table Point limestone was uplifted along faults and matrix-poor limestone breccias were deposited as a series of thick sheets or wedges. These massive breccias sit with sharp contacts within the shales and in basal beds of the Goose Tickle flysch. The apparent lack of erosion at the base is puzzling for such massive deposits. However, the upper most breccia at Cape Norman Bay appears to pass laterally into unbrecciated Table Point limestone. This may suggest that these limestone breccias formed essentially in place at the foot of steep, fault-controlled scarps that were repeatedly active during the early history of the shale basin.

In the east of the basin, Table Point limestone was uplifted together with the Black Cove shales. Probably weakened by tectonic instability and perhaps tilted at fairly steep angles, large masses of limestone and shale slumped off the highs to disintegrate into widely distributed debris flows of the Cape Cormorant Formation. Elevated tectonic islands of eroded Table Point limestone left stranded above the sea floor were frequently cemented by silica and dolomite. This cement either developed as a deep-water submarine hardground or it formed later and diagenetically at the shale-limestone contact since thin measures of Black Cove shale overlie the eroded and cemented crust at Burnt Island. Here, there are also thin beds of Cape Cormorant Formation within the basal part of the Goose Tickle flysch; this suggests there were repeated pulses of uplift and erosion. Uplift, erosion and deposition of thin debris flows indeed continued as sandy flysch of the Goose Tickle began to flood southward along the basin. The presence in some of the thicker breccias of tabular bedded limestone lithoclasts, similar to slope limestones of the Table Cove Formation of Klappa *et al.* (1980), suggests uplift of a Table Head Group section outside the map area.

A long narrow slice of Table Point limestone and black shales that occurs in the structurally complex rocks of the east side of Woody Point may have been detached from its parent and transported into the shale basin as an olistolith. Where hard-rock thrusts of limestone on shale are observed, there are always zones of intense shearing at the base of the limestones. However, in the narrow slice discussed here, the base is not sheared but it is uneven and lumpy, suggesting that lumps of limestones have been plucked from it along an uneven surface. Also, the underlying sediments of the basal Goose Tickle Formation are not sheared although they are overturned. Drag folds in the Goose Tickle immediately below the 'olistolith' indicate that it slid into place from the west. The western margin of the olistolith is nearly vertical and are locally cemented by a chert-dolomite crust. Nearby on the same margin the limestone has broken down into a pocket of lumpy breccia with shale incorporated around the limestone lumps. All these features are indicative of early postdepositional processes and support an 'olistolith' origin for the limestone wedge.

STRUCTURE

The map area contains three contrasting structural terranes. The first, in the west, consists of gently eastward-dipping autochthonous carbonates. The most conspicuous structures are steep, north to northeast-trending faults.

The second terrane, east of the carbonates is generally bordered on the west by a splay fault of the Ten Mile Lake Fault, and on the east by the Ordovician siliciclastic terrane. In the second structural terrane, some carbonates are clearly parautochthonous, and limestones have moved westward above thin shale horizons, resulting in intense shearing at the soles of the thrusts. The imbricated succession was then deformed by northeast-trending, open and tight, westward-verging, overturned folds. Cleavage is locally developed and limestones are highly sheared in zones of high strain.

The third structural terrane is mostly in fault contact with the second terrane. It consists of tightly folded Goose Tickle flysch, northwest-directed thrust slices of Ordovician limestone, and Northwest Arm Formation mélange. Folds are overturned and westward facing. They trend northeast to north, have variable plunges of 5 to 25° southwest and northeast, and have a well developed, axial planar to fan cleavage. Thrusts have developed at the crests of pinched, west-verging anticlines that are cored by Table Point limestone.

Tuke (1968) showed the Northwest Arm mélange as imbricated with the Goose Tickle flysch. Williams and Smyth

(1983) concluded that the contact between the two rock units is a somewhat soft, irregular, tectonic contact. The contact in Pistolet Bay and Hare Bay is defined by a strongly flattened shale containing thin sandstone and intraclastic conglomerate beds.

The Northwest Arm Formation, itself, has been described as a mélange of sedimentary blocks in a chaotic green and black shale matrix (Williams and Smyth *in* Bostock *et al.*, 1983). However, green and black layering is clearly present in the shales. In addition, facing directions ascertained by grading, sole marks and cross-lamination in dismembered beds of the 'mélange' show that there is some continuity to the dismembered strata. These facing directions show that much of the succession was inverted and folded prior to deformation by the later, main phase of northeast-trending folds.

A mélange of similar character, but composed of Goose Tickle sediments in Wild Bight, Hare Bay, lends support to this idea. The Goose Tickle mélange is part of an inverted succession. Just west of Fournier Point, inverted Table Point limestone structurally overlies Black Cove shale and Goose Tickle flysch, which has disintegrated to mélange. Enclosed in the mélange are rafts of Cape Cormorant Formation and Table Point limestone breccia, as well as siliciclastic components. Facing directions in thick sandstone beds in the Goose Tickle indicate the presence of recumbent folds in the melange that are refolded by the later northeast folds. Type 1 and type 3 (Ramsay, 1967) interference patterns also occur, confirming the early recumbent structure.

Long, sinuous, northeast-trending faults with normal and reverse throws extend along the length of the carbonate belt. The main fault system is the Ten Mile Lake Fault zone which is a braided system of northeast- and north-trending splay faults. Narrow wedges of upthrown and downthrown strata occur within the zone. West-, northwest-, and southwest-trending faults also occur, in many instances these offset the northeast-trending faults. Downthrow on many of these faults is to the north.

These basic structural elements provide the framework for a tectonic history of the area. Infill of the Middle Ordovician flysch basin was terminated by emplacement of recumbently folded and dismembered sediments of the Northwest Arm Formation. During this early phase of Taconic deformation, thin skins of carbonate rock were imbricated with the Goose Tickle shales. These early structures were subsequently deformed by a later phase of northeast-trending, west-verging folds and westward overthrusting. The flysch and carbonate terranes were decoupled and a regional penetrative cleavage was developed in the more easterly terrane. Vertical displacement along high angle faults determined present outcrop patterns.

MINERALIZATION

Pyrite and sphalerite mineralization including some galena is widespread in the map area. The numerous showings can be essentially subdivided into two strata-bound zones. The first zone occurs in epigenetic dolostones and spar and matrix breccias that occur in the lower half and along the base of the Boat Harbour Formation. In some instances, the breccias step down into the Watts Bight Formation. Included in this zone is the Round Pond Prospect, reported to contain 152,000 tonnes of 2.5 percent Zn, Rhodes (1970, 1971). Sphalerite showings at Hidden Pond and Twin Ponds lie within the matrix and spar breccia bodies of this same interval. Pyrite is generally the most common mineral but sphalerite and galena are disseminated in some bodies. Showings near Watsons Brook and at Twin Ponds occur in higher intervals of the Boat Harbour Formation where dark-gray dolomites and pseudobreccia replace limestone beds. Small pods of matrix breccia are also present.

The second group of showings is in dolomites that have replaced limestones of the second and third members of the Catoche Formation. North Boat Harbour showings 1 to 5 (Hibbard, 1984a) and those at North Sawmill Pond (Hibbard, 1984b) and at Whale Pond occur in these epigenetic dolostones. The red-brown to green-yellow, fine to coarsely crystalline sphalerite is generally disseminated in pseudobreccia or more massive dolostones close to limestone-dolostone contacts.

Epigenetic dolostones that replace limestones at the base of the Table Point Formation (locality 4, Figure 1) and at the new St. Anthony airport contain sphalerite mineralization. Coarse brown-red crystals of sphalerite occur in dark gray to gray, dolospar-veined, fine to medium grained, crystalline dolostone at the lineament at locality 4. At St. Anthony airport, green sphalerite occurs in a pod of white crystalline dolomite that is intensely veined.

Sphalerite mineralization in the map area has been assumed to compare in genesis and timing to that at Daniel's Harbour (summarized by Cumming *in* Bostock *et al.*, 1983). When stratigraphic mapping began in the map area in 1977 and 1979 it became clear that many of the numerous showings, including the Round Pond Prospect, occurred in the Boat Harbour Formation. This stratigraphic interval, 250 m below the host horizon of the Daniel's Harbour Mine, lead Knight (1980, 1984) to suggest a second strata-bound target besides the secondary dolostones of the Catoche Formation. Dolomitization and creation of spaces in the Boat Harbour Formation was linked tentatively to the Boat Harbour 'disconformity'.

There is now sufficient evidence in the area and elsewhere on the Northern Peninsula to confirm late Arenig faulting of the platform and the presence of a late Arenig hiatus that essentially coincides with the contact between the St. George and Table Head groups. Matrix breccias, which formed in rocks of the Boat Harbour Formation, may have been controlled in part by the faulting. The faults, in particular the precursor to the Ten Mile Lake Fault system fractured the carbonates, creating fracture permeability. This provided subterranean channelways for solutions that not only caused dissolution but also extensive dolomitization. Later, when metal-bearing brines entered the system, they formed sites of low-grade mineralization. Clearly, during late Arenig karstification, the Boat Harbour strata could have been readily affected as suggested in Figure 4. The presence of sphalerite mineralization in dolomitized strata of the Table Head Group suggests metals were precipitated following the deposition of the Table Head Group.

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ORDOVICIAN BIOSTRATIGRAPHIC INVESTIGATIONS, GREAT NORTHERN PENINSULA, WESTERN NEWFOUNDLAND

W.D. Boyce
Newfoundland Mapping Section

ABSTRACT

It was determined that Barnes and Tuke's (1970) conodont samples were collected from a distinctive 1.6 m thick algal mound bed 3.1 m above the Boat Harbour 'pebble bed'. Barnes and Tuke's data support Boyce's (1979, 1983a, b) and Stouge's (1982) Ross-Hintze Zone G_2 *age determination for the upper member of the Boat Harbour Formation. Trilobite and conodont data indicate that the Catoche Formation is as young as Ross-Hintze Zone I on the Port au Choix Peninsula and on Burnt Island.* Bolbocephalus convexus *(Billings) and* Illaenus *sp. nov. occur more commonly in mound beds of the Catoche Formation than in the more typical limestones of the formation. Additional* Phyllograptus*-bearing horizons were discovered in the Catoche Formation at Laignet Point and Eddies Cove West.*

INTRODUCTION

The Ordovician carbonate deposits of the Great Northern Peninsula are the object of regional taxonomic-biostratigraphic studies aimed at correlating their trilobite faunas with those of the standard zonations of Ross (1951) and Hintze (1953). This report discusses new trilobite and graptolite material obtained from Port au Choix Peninsula, Eddies Cove West, Boat Harbour, Cape Norman, Schooner Island and Burnt Island (Figure 1). The sampling results augment and update the work of Fortey (1979), and Boyce (1983a, b, 1985). Lithostratigraphic divisions that were studied in 1985 belong to the Boat Harbour and Catoche formations (St. George Group). Their sedimentology and lithology are described in detail by Knight (1983, *this volume*).

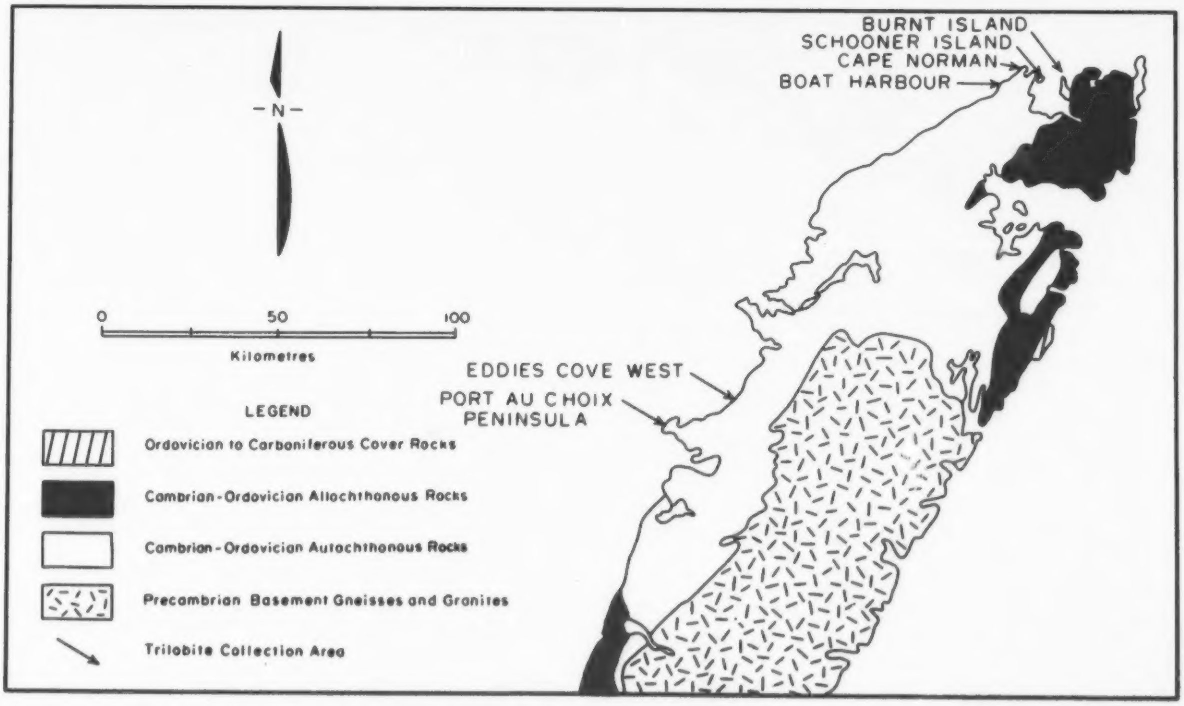

BURNT ISLAND
SCHOONER ISLAND
CAPE NORMAN
BOAT HARBOUR
N
0
50
100
Kilometres
EDDIES COVE WEST
PORT AU CHOIX PENINSULA
LEGEND
Ordovician to Carboniferous Cover Rocks
Cambrian-Ordovician Allochthonous Rocks
Cambrian-Ordovician Autochthonous Rocks
Precambrian Basement Gneisses and Granites
Trilobite Collection Area

Figure 1: *Geological elements of the Great Northern Peninsula and trilobite collection areas discussed in this report.*

This project is a contribution to the Canada-Newfoundland Mineral Development Agreement, 1984-1989

DETAILED BIOSTRATIGRAPHIC WORK

Detailed biostratigraphic sampling for Early Ordovician trilobites and conodonts continued in the Boat Harbour and Catoche formations of the St. George Group. Sampling was done in the following areas: a) Barbace, Catoche and Laignet Points on the Port au Choix Peninsula, b) Eddies Cove West, c) Boat Harbour, and d) Cape Norman.

Port au Choix Peninsula

At Barbace Point and Catoche Point, sampling was done to fill gaps left in the sections by Fortey (1979) and Boyce (1983a, 1985). Lime boundstone mounds and their associated grainstone/packstone interfill were sampled at Catoche Point. This was done to determine if the trilobite faunas of these beds were markedly different from those in the more typical, rubbly weathering, lime mudstones/wackestones and lime packstones/grainstones of the Catoche Formation. The following species were collected from the mound beds:

Bathyurellus abruptus Billings

Bathyurellus platypus Fortey

Bolbocephalus convexus (Billings)

Catochia glabra Fortey

Illaenus sp. nov.

Ischyrotoma anataphra Fortey

Isoteloides latimarginatus Fortey

Jeffersonia angustimarginata Boyce, 1983b (see Stouge and Boyce, 1983; Plate 13, figure 4).

Jeffersonia timon (Billings)

Petigurus nero (Billings)

Punka flabelliformis Fortey

Strigigenalis caudata (Billings)

Uromystrum sp. cf. *U. affine* (Poulsen) of Fortey (1979)

Illaenus sp. nov. was recovered for the first time from the Catoche Point section. This species was previously only known from algal-sponge mound biofacies of the Catoche Formation at Forked Feeder Pond (Port Saunders (12I/11) map area), on Burnt Island in Pistolet Bay, and along the road to Roddickton (Boyce, unpublished data). *Bolbocephalus convexus* (Billings) is the only other trilobite besides *Illaenus* sp. nov. that occurs more commonly in the boundstone mound beds than in the more typical Catoche Formation limestones.

The tidal island at Laignet Point was sampled in detail for trilobites for the first time. It is located at the extreme western tip of the Port au Choix Peninsula. The Catoche Formation here comprises thin bedded, laminated, sparsely bioturbated, platy lime mudstones and grainstones, which are locally peloid rich. The strata were previously referred to as the Laignet Point Member by Knight (1977, 1978), Stouge (1982) and Stouge and Boyce (1983); however, the term is no longer regarded as valid (Knight, personal communication, 1985).

Stouge (1982, Figures 3 and 4) and Stouge and Boyce (1983, Figure 2.2) reported eleven biostratigraphically significant conodont species from the Laignet Point Member on the tidal island. These species also occur in the Pogonip Group at Ibex, Utah (Ethington and Clark, 1981). The species and their Ross-Hintze zonal ranges are as follows:

Drepanodus parallelus Branson and Mehl s.f.
- Zone B to Zone L

Scolopodus? gracilis Ethington and Clark s.f.
- Zone E to Zone M

Oistodus inaequalis Pander s.f.
- Zone G_1 to Zone J

'Scolopodus' quadraplicatus Branson and Mehl s.f.
- Zone D to Zone I

Drepanodus? gracilis (Branson and Mehl) s.f.
- Zone G_1 to Zone I

Oepikodus communis (Ethington and Clark)
- Zone G_2 to Zone J

Drepanodus arcuatus Pander - Zone E to Zone J

Tropodus comptus (Branson and Mehl)
- Zone G_1 to Zone I

?Microzarkodina marathonensis (Bradshaw)
- Zone G_2 to Zone N

Semiacontiodus asymmetricus (Barnes and Poplawski)
- Zone H to Zone L

?Paroistodus parallelus (Pander) - Zone G_1 to Zone I

With reference to Ethington and Clark (1981, Figure 3), the minimum age range of the above species assemblage is Ross-Hintze Zone H to Zone I.

Macrofossils are generally difficult to find on the tidal island. There are a few rich layers, however, which contain articulate brachiopods, cephalopods, echinoderm debris, gastropods, graptolites, ostracodes, receptaculitids and trilobites. Trilobites were collected from nine horizons over a 9.3 m stratigraphic interval. The following species were obtained:

Petigurus sp. nov. (= *Petigurus* sp. indet., Fortey, 1979)

Goniotelus? sp. cf. Ross (1951; Plate 15, figure 12)

Petigurus nero (Billings)

Punka flabelliformis Fortey

Ischyrotoma anataphra Fortey

Jeffersonia timon (Billings)

Strotactinus insularis (Billings)

Isoteloides latimarginatus Fortey

Benthamaspis gibberula (Billings)

Illaenus sp. nov.

Catochia glabra Fortey

Bathyurellus platypus Fortey

Punka sp. nov. (= *Punka* sp. indet., Fortey, 1979)

Most of the above species also occur in the stratigraphically lower Catoche Point section. The presence of *Benthamaspis gibberula* (Billings) indicates that the beds on the tidal island are no older than early Arenig Ross-Hintze Zone H (Fortey, 1979; Boyce, 1985). The presence of *Goniotelus?* sp. cf. Ross (1951) further suggests that these beds are of early Arenig Ross-Hintze Zone I age, as *Goniotelus?* sp. of Ross (1951) occurs in Zone I in Utah (Ross, 1951, Plate 15, figure 12).

During the sampling on the island, a *Phyllograptus* - rich horizon was discovered. This horizon occurs 4.81 to 4.95 m above the *Phyllograptus* horizon documented by Boyce (1985, Figure 2). Either of these horizons may be the one originally reported by Kindle (1945).

Eddies Cove West

Lime boundstone beds of the Catoche Formation, originally sampled by Boyce (1983a), were resampled in more detail to determine if their trilobite faunas differed from those of the more typical Catoche Formation limestones. The following species were collected:

Bathyurellus abruptus Billings

Bathyurellus platypus Fortey

Benthamaspis gibberula (Billings)

Bolbocephalus convexus (Billings)

Ischyrotoma anataphra Fortey

Isoteloides latimarginatus Fortey

Jeffersonia angustimarginata Boyce, 1983b (see Stouge and Boyce, 1983; Plate 13, figure 4).

Jeffersonia timon (Billings)

Petigurus nero (Billings)

Strigigenalis caudata (Billings)

Although both *Bolbocephalus convexus* (Billings) and *Illaenus* sp. nov. are common in mound beds of the Catoche Formation elsewhere, only *Bolbocephalus convexus* (Billings) was recovered from the mounds of the Eddies Cove West section.

Phyllograptus was recovered for the first time at Eddies Cove West from the uppermost lime boundstone mound bed of the Catoche Formation. It is probably the same species as that collected from the upper beds of the Catoche Formation on the Port au Choix Peninsula (Boyce, 1985, *this report*).

Boat Harbour

The exact stratigraphic positions of Barnes and Tuke's (1970) conodont samples A and B were identified (see Figure 2). The samples were originally collected from grainstones between algal mounds (R.K. Stevens, personal communication, 1985) and the geographic location of each was visited to find the appropriate unit. Both sampled localities were found to definitely occur above the Boat Harbour pebble bed of Knight (1977, 1978, 1980), and Boyce (1978, 1983b). Furthermore, it was determined that both samples were obtained from the same bed, although they were taken 1 km apart (see Figure 2) and Barnes and Tuke (1970, Table 1) documented slightly differing species assemblages.

The bed from which the samples were obtained is distinctive. It is about 1.6 m thick and consists of algal mounds with highly fossiliferous grainstones between them. The base of the bed occurs about 3.1 m above the top of the 'pebble bed'. The mounds are large, isolated, steep-sided, circular to slightly elliptical, and up to 1.5 m in diameter (Boyce, 1983b).

Twenty-one conodont species were obtained by Barnes and Tuke (1970, Table 1). Of these, ten form an assemblage that is also recognizable in the Pogonip Group at Ibex, Utah (Ethington and Clark, 1981). The species and their Ross-Hintze zonal ranges are as follows:

?Acodus sp. 3 Ethington and Clark, 1981 - Zone F to Zone G_2

Drepanodus sp. 1 Ethington and Clark, 1981 - Zone D to Zone J

Drepanodus parallelus Branson and Mehl s.f. - Zone B to Zone L

Oistodus inaequalis Pander s.f. - Zone G_1 to Zone J

aff. *Oneotodus simplex* (Furnish) - Zone E to Zone I

'Scolopodus' emarginatus Barnes and Tuke - Zone G_2 to Zone I

Scolopodus? gracilis Ethington and Clark s.f. - Zone E to Zone M

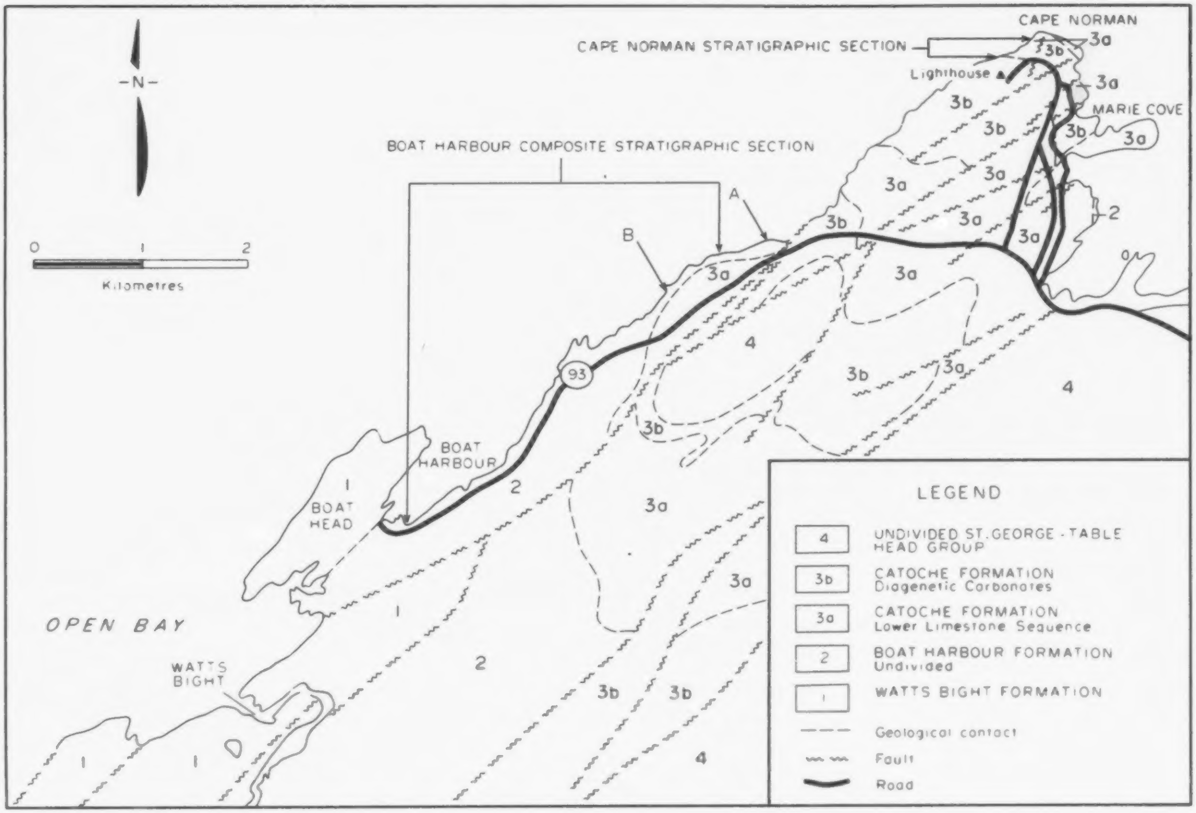
Scolopodus multicostatus Barnes and Tuke - Zone G_2

'Scolopodus' quadraplicatus Branson and Mehl s.f. - Zone D to Zone I

Ulrichodina abnormalis (Branson and Mehl) - Zone G_1 to Zone I

With reference to Ethington and Clark (1981, Figure 3), the above species assemblage is firmly indicative of an early Arenig Ross-Hintze Zone G_2 age. The biostratigraphic conclusion of Boyce (1979, 1983a, b) and Stouge (1982) as to the age of the Boat Harbour Formation above the 'pebble bed' is thus supported by the data of Barnes and Tuke (1970).

Hystricurus sp. cf. *H. crassilimbatus* Poulsen and *Peltabellia* sp. cf. *P. crassimarginata* (Cullison) were recovered for the first time from the same algal mound bed at Boat Harbour. *Hystricurus crassilimbatus* Poulsen occurs in the Cape Weber Formation of East Greenland (Poulsen, 1937, pages 47, 48; Plate 5, figures 5-8) and Ellesmere Island (Poulsen, 1946, page 327, Plate XXII, figure 18). It is also reported from the Deadwood Formation of North Dakota by Lochman (1966, page 533; Plate 65, figure 41). *Peltabellia crassimarginata* (Cullison) is present in the standard deposits of the upper part of the Jeffersonian Stage *sensu* Flower (1978) in Missouri-northern Arkansas. There it occurs in the Blackjack Member of the Theodosia Formation of the Jefferson City Group (Collison 1944, pages 75-77; Plate XXXV, figures 17-22).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0
1
2
Kilometres
CAPE NORMAN
CAPE NORMAN STRATIGRAPHIC SECTION
Lighthouse
MARIE COVE
BOAT HARBOUR COMPOSITE STRATIGRAPHIC SECTION
A
B
93
BOAT HARBOUR
BOAT HEAD
OPEN BAY
WATTS BIGHT
1
2
3a
3b
4
LEGEND
4 UNDIVIDED ST. GEORGE - TABLE HEAD GROUP
3b CATOCHE FORMATION Diagenetic Carbonates
3a CATOCHE FORMATION Lower Limestone Sequence
2 BOAT HARBOUR FORMATION Undivided
1 WATTS BIGHT FORMATION
Geological contact
Fault
Road

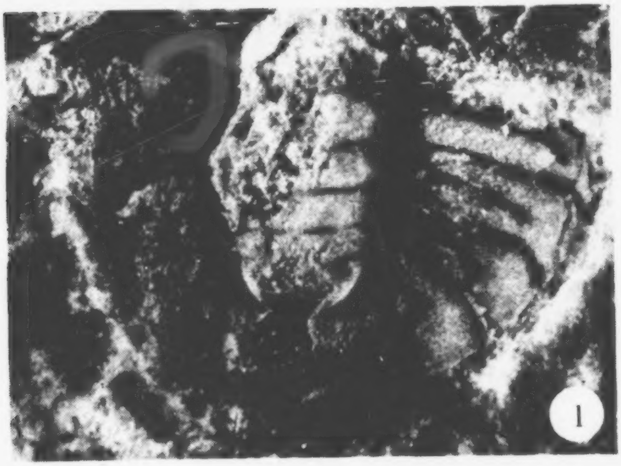
Figure 2: *Geology of the Boat Harbour - Cape Norman study area and location of measured stratigraphic sections of Boyce (1983b, this report). Geology modified from Knight and Edwards (1978a, b). A, B indicate sampled conodont localities of Barnes and Tuke (1970).*

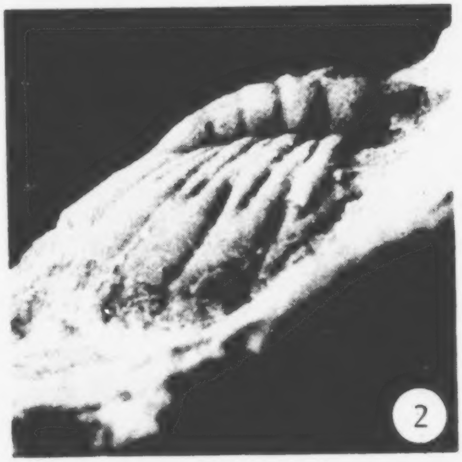
Plate 1: *Bolbocephalus* sp. nov.

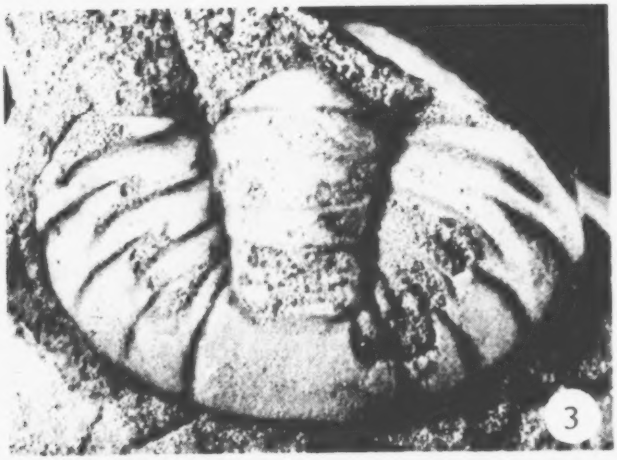
Figures 1, 2: *Pygidium, dorsal and lateral views, MMH 3714 (the original of Poulsen, 1937; Plate 8, figure 2), x 9, Cape Weber Formation, Ella Island, East Greenland. MMH = Geologisk Museum, University of Copenhagen, Copenhagen, Denmark.*

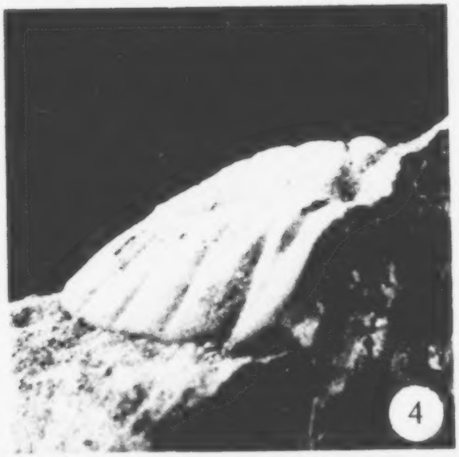
Figures 3, 4: *Pygidium, dorsal and lateral views, NFM F-209, x 6, Catoche Formation, Cape Norman, Newfoundland. NFM = Newfoundland Museum, St. John's, Newfoundland, Canada.*

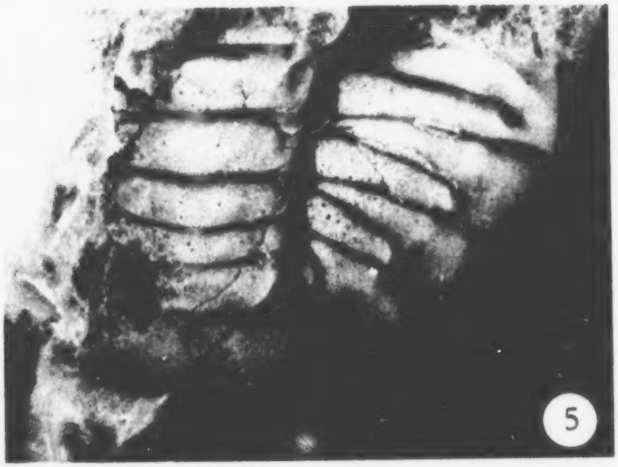
Figures 5, 6: *Pygidium, dorsal and lateral views, G.S.C. 82296, x 3.75, Catoche Formation, Burnt Island, Newfoundland. G.S.C. = Geological Survey of Canada, Ottawa, Ontario, Canada. Specimen originally collected by C.H. Kindle (1945).*

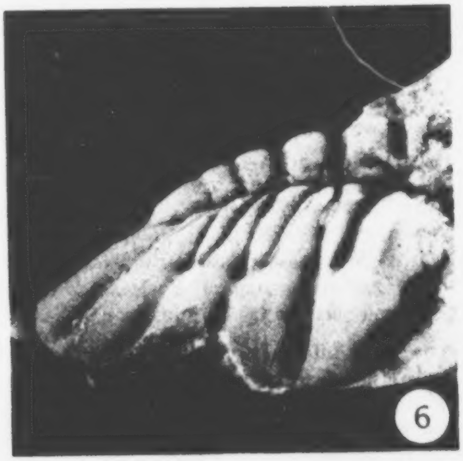












Cape Norman

Limestones of the Catoche Formation at Cape Norman were the object of detailed biostratigraphic sampling for trilobites and conodonts. The section exposed north of the lighthouse (see Figure 2) was previously investigated by Whittington (1968), Whittington and Kindle (1969) and Boyce (1978, 1979, 1983b). Boyce (1983b) documented seven species from twenty sampled horizons within a 17 m stratigraphic interval. This past summer, thirty-three horizons were sampled within a 21 m stratigraphic interval. The closer sample spacing and sampling of the additional 4 m (lower in the section) has resulted in a considerable revision of the biostratigraphic ranges of the species. Most have substantially longer ranges than indicated by Boyce (1983b, Figure 3.1). In addition, the number of species identified has been doubled. The revised biostratigraphic chart will be published later. The following species were collected:

Trilobita

Bathyurellus abruptus Billings

Bolbocephalus convexus (Billings)

Bolbocephalus sp. nov. (= Genus et sp. ind., Poulsen, 1937; Plate 8, figure 2; see also Plate 1, *this report)*

Catochia ornata Fortey

Illaenus sp. nov.

Ischyrotoma parallela Boyce, 1983b (see Stouge and Boyce, 1983; Plate 13, figure 3)

Petigurus nero (Billings)

Uromystrum affine (Poulsen)

Jeffersonia timon (Billings)

Ischyrotoma anataphra Fortey

Uromystrum sp. cf. *U. affine* (Poulsen) of Fortey (1979)

Benthamaspis conica Fortey

Benthamaspis sp. cf. *B. conica* Fortey

Strotactinus insularis (Billings)

Cephalopoda

Cassinoceras wortheni (Billings)

Protocycloceras lamarcki (Billings)

Whittington and Kindle (1969, page 659) reported the trilobite *Carolinites* sp. from Cape Norman. Fortey (1979) identified *Isoteloides peri* Fortey, *Punka flabelliformis* Fortey and *Benthamaspis* sp. cf. *B. gibberula* (Billings) from collections obtained by Whittington and Kindle.

The Catoche Formation trilobite fauna at Cape Norman correlates broadly with the early Arenig Ross-Hintze Zone G_2 to Zone H fauna of the lower 30 m of the Catoche Point section of Fortey (1979, Figure 11) and Boyce (1985, Figure 2) on the Port au Choix Peninsula.

The cephalopod *Protocycloceras lamarcki* (Billings) also occurs in the Romaine Formation of the Mingan Islands, Quebec (Billings, 1865) and in the Oxford Formation in southeastern Ontario (Billings, 1865).

RECONNAISSANCE BIOSTRATIGRAPHIC WORK

Reconnaissance biostratigraphic sampling for Early Ordovician trilobites and conodonts commenced in the Boat Harbour and Catoche formations on Schooner Island and Burnt Island in Pistolet Bay. These islands have not been examined in detail since the investigations of Kindle (1945) and Johnson (1949). The upper part of the Catoche Formation consists of fossiliferous limestone on the islands, whereas in most other places on the Great Northern Peninsula this stratigraphic interval consists of diagenetic dolostones. The dolostones are generally unfossiliferous except for local silicified cephalopods and/or gastropods.

Schooner Island

Twelve collections were made on Schooner Island. Three were obtained from the upper member of the Boat Harbour Formation. They collectively yielded the following trilobites:

Peltabellia knighti Boyce, 1983b (see Stouge and Boyce, 1983; Plate 16, figures 3-5)

Jeffersonia angustimarginata Boyce, 1983b (see Stouge and Boyce, 1983; Plate 13, figure 4)

Bolbocephalus convexus (Billings)

Bolbocephalus stevensi Boyce, 1983b

Isoteloides peri Fortey

Strigigenalis brevicaudata Boyce, 1983b (see Stouge and Boyce, 1983; Plate 16, figure 6)

The above fauna correlates with the early Arenig Ross-Hintze Zone G_2 fauna that occurs above the 'pebble bed' and its equivalents in the upper member of the Boat Harbour Formation at Boat Harbour, Barbace Point and Eddies Cove West (Boyce 1983a, b, 1985).

Nine collections were obtained from the Catoche Formation on Schooner Island. The lower burrowed limestone member and the middle limestone mound member of Knight (*this volume*) were sampled and the following trilobite species identified:

Bathyurellus abruptus Billings

Benthamaspis sp. undet.

Bolbocephalus convexus (Billings)

Jeffersonia angustimarginata Boyce, 1983b (see Stouge and Boyce, 1983; Plate 13, figure 4)

Uromystrum affine (Poulsen)

Isoteloides peri Fortey

Punka sp. nov. (=*Punka* sp. indet., Fortey, 1979)

Petigurus nero (Billings)

Illaenus sp. nov.

The above fauna correlates with the early Arenig Ross-Hintze Zone G_2 to Zone H faunas of the lower part of the Catoche Formation at Boat Harbour, Cape Norman, Eddies Cove West and Barbace Point (Boyce 1983a, b, 1985).

Burnt Island

Eighteen collections were obtained from the Catoche Formation on Burnt Island. The upper burrowed limestone member and the white limestone member of Knight (*this volume)* were sampled and the following trilobites recovered:

Bolbocephalus convexus (Billings)

Bolbocephalus sp. nov. (= Genus et sp. ind., Poulsen, 1937; Plate 8, figure 2; see also Plate 1, *this report)*

Gignopeltis rarus (Billings)

Ischyrotoma sp. cf. *I. anataphra* Fortey

Jeffersonia sp. cf. *J. jenii* Cullison

Strotactinus sp. cf. *S. insularis* (Billings)

Uromystrum affine (Poulsen)

Uromystrum sp. undet.

The Burnt Island fauna most probably correlates with the early Arenig Ross-Hintze Zone H to Zone I fauna of the upper part of the Catoche Formation at Catoche Point and Laignet Point on the Port au Choix Peninsula.

Gignopeltis rarus (Billings) and *Bolbocephalus convexus* (Billings) also occur in the Oxford Formation of southeastern Ontario (Ludvigsen, 1979; Plate 1, figures 4-6). *Uromystrum affine* (Poulsen) and *Bolbocephalus* sp. nov. (see Plate 1, *this report)* are also present in the Cape Weber Formation of East Greenland (Poulsen, 1937; Plate 7, figures 6, 7, and Plate 8, figure 2).

ACKNOWLEDGEMENTS

Dr. C. H. Kindle (Nyack, New York) provided access to his superb western Newfoundland trilobite collection. Drs. T. E. Bolton (Geological Survey of Canada) and S. Floris and V. Poulsen (Geologisk Museum - University of Copenhagen) are also acknowledged for the loan of trilobite material. Stephen Ash discovered the graptolites on the Laignet Point tidal island. His keen-eyed field assistance was greatly appreciated. His attempts to provide video competition are also duly acknowledged. Drs. N.P. James, I. Knight and S.H. Williams provided stimulating field discussions. Austin Patey (River of Ponds), Lawrence Patey and his family (Hawkes Bay) and Lyle Campbell and his family (Cape Norman) are thanked for their assistance and hospitality. Drs. I. Knight and S.P. Colman-Sadd critically read the manuscript.

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BIOSTRATIGRAPHIC AND PALEOENVIRONMENTAL SIGNIFICANCE OF PALAEONISCID FISH AND VASCULAR PLANT REMAINS FROM THE SNAKES BIGHT FORMATION (ANGUILLE GROUP), CODROY AREA, SOUTHWESTERN NEWFOUNDLAND

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Newfoundland Mapping Section

ABSTRACT

The Codroy area was visited in order to sample the Snakes Bight Formation (Anguille Group) more extensively for palaeoniscid fish and vascular plant fossils, and to determine the depositional environment of the formation. The plant species Lepidodendropsis corrugata *(Dawson) was obtained from the Snakes Bight Formation for the first time. Closer examination of the formation failed to yield any diagnostic marine fossils. The conclusion of previous workers that the Snakes Bight Formation is of lacustrine origin is probably valid.*

INTRODUCTION

The Snakes Bight Formation (Anguille Group) comprises thinly bedded black siltstones, mudstones and shales, and thinly to thickly bedded gray sandstones. It also includes minor conglomerates, intraformational slump deposits and carbonate rocks (Baird and Coté, 1964; Knight, 1983). Past workers have generally interpreted the formation as a freshwater lacustrine deposit (Baird and Coté, 1964; Belt, 1969; Knight, 1983; Boyce, 1985; Dean and Meyer, 1985), even though it was possible that it might be of marine origin (Knight, 1983, page 31).

Articulated fish remains and vascular plant fossils were discovered in June, 1984, near the top of the Snakes Bight Formation at Shoal Point, near Codroy, by P. L. Dean, J. R. Meyers, A. Best and D. Andrews (Boyce *et al.*, 1984; Boyce, 1985). The area was revisited this past summer in order to obtain more extensive fish and plant collections, and to determine the depositional environment of the Snakes Bight Formation.

BIOSTRATIGRAPHIC SIGNIFICANCE OF THE COLLECTED FLORA AND FAUNA

Collections were obtained from the Snakes Bight Formation on the northern and southern flanks of an anticline at Shoal Point and at the Cape Anguille lighthouse (see Knight, 1983, Map 82-1, and Dean and Meyer, 1985, Figure 4).

On the southern flank of the anticline, there are at least two productive horizons for fossil fish in the Snakes Bight Formation. They are separated by approximately 2 m and have collectively yielded the following fossils (see also Boyce, 1985).

Plantae

Aneimites acadica Dawson
Asterocalamites scrobiculatus (Schlotheim)
Lepidodendropsis corrugata (Dawson)

Palaeoniscida (Colbert, 1980; Moy-Thomas and Miles, 1971; Romer, 1966)

Acrolepis sp. undet.
?Canobius sp. undet.
Elonichthys browni (Jackson)
Elonichthys ellsi Lambe
Rhadinichthys sp. cf. *R. alberti* (Jackson)

Aneimites acadica Dawson was recovered from the northern flank of the anticline.

At the Cape Anguille lighthouse, *Aneimites acadica* Dawson was collected from the Snakes Bight Formation within 10 to 20 m stratigraphically below its southern contact with the overlying Friars Cove Formation.

Age of the Snakes Bight Formation (top)

Aneimites acadica Dawson, *Lepidodendropsis corrugata* (Dawson) and *Asterocalamites scrobiculatus* (Schlotheim) occur in the Horton Bluff and Cheverie Formations (Horton Group) of Nova Scotia (Bell, 1960). *Aneimites acadica* Dawson and *Lepidodendropsis corrugata* (Dawson) are also present in the Albert Formation of southeastern New Brunswick (Lambe, 1910; Bell, 1960).

A species of *Acrolepis* occurs in the Horton Bluff Formation of Nova Scotia (Dawson, 1878; Carroll *et al.*, 1972). *Elonichthys browni* (Jackson), *E. ellsi* Lambe, *Rhadinichthys alberti* (Jackson) and a species of *Canobius* are found in the Albert Formation of New Brunswick (Lambe, 1910; Gussow, 1953; Greiner, 1974).

Aneimites acadica Dawson has been reported from Lower Carboniferous strata in Scotland (White, 1927). Species of *Acrolepis*, *Canobius*, *Elonichthys* and *Rhadinichthys* are also

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This project is a contribution to the Canada-Newfoundland Mineral Development Agreement, 1984-1989

common in Scottish Lower Carboniferous strata (Traquir, 1903; Moy-Thomas and Bradley-Dyne, 1938; Schram, 1983).

Bell (1960), Playford (1963) and Barss *in* Hacquebard (1972) assigned an Early Carboniferous, Late Tournaisian (Early Mississippian) age to the Horton Bluff and Cheverie Formations of Nova Scotia, and the Albert Formation of New Brunswick, based on their macroflora and microflora. Because the fossil plants and fish in the Snakes Bight Formation so closely compare at the specific and generic levels with those in the above formations, a similar age is indicated. The upper part of the Snakes Bight Formation is therefore Early Carboniferous, Late Tournaisian (Early Mississippian) in age (see Boyce, 1985, Figure 2).

PALEOENVIRONMENT OF THE SNAKES BIGHT FORMATION

Knight (1983) pointed out the lithological similarity of the Snakes Bight Formation to the lacustrine Albert Formation of New Brunswick (Greiner, 1962, 1974) and the lacustrine argillaceous middle member of the Horton Bluff Formation of Nova Scotia (Carroll *et al.*, 1972; Hesse and Reading, 1978). Boyce (1985) discussed the difficulties of using the plant and fish fossils alone in assessing the depositional environment of the Snakes Bight Formation. Closer examination of the upper part of the formation this past summer failed to yield any diagnostic marine fossils (such as brachiopods, bryozoa, cephalopods, corals, echinoderms, sponges or trilobites), despite a determined search. This suggests that the Snakes Bight Formation is a freshwater lacustrine deposit as concluded by Knight (1983) and Boyce (1985).

ACKNOWLEDGEMENTS

Stephen Ash found the best fish specimen this past summer. His enthusiastic field assistance is gratefully acknowledged. K. Seymour (Royal Ontario Museum, Toronto), R.G. Day (National Museum of Canada, Ottawa), T.E. Bolton (Geological Survey of Canada, Ottawa) and D. McAlpine (New Brunswick Museum, Saint John) kindly allowed me to examine relevant fish and plant fossils (type and comparative material) from the Albert Formation at their respective institutions. Drs. I. Knight and S.P. Colman-Sadd are thanked for critically reading the manuscript.

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Mineral Development Division, Report 86-1, pages 173-175

ASPECTS OF STRATIGRAPHY AND SHALE GEOCHEMISTRY IN SEDIMENTARY ROCKS OF THE HUMBER ARM GROUP

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INTRODUCTION

This report deals with aspects of a Ph.D. project presently underway at Memorial University. The project is concentrated on the Cook's Brook and Middle Arm Point formations, a suite of shales, limestone turbidites, carbonate conglomerates and cherts that occurs in the middle part of the Humber Arm Group, situated within the Bay of Islands, western Newfoundland. These late Middle Cambrian to Early Ordovician sedimentary rocks appear to be the deep-water equivalents of the Cow Head Group to the north.

The aims of the project are: 1) to define the stratigraphic framework of Middle Cambrian to Lower Ordovician deep-water sedimentary rocks in this area, 2) to describe and interpret the sedimentology of these sequences, and 3) to examine changes in shale geochemistry through the section as a potential aid in correlation, and a possible indicator of depositional environment.

Collaboration with Newfoundland Department of Mines and Energy personnel has been in three main areas: shale geochemistry with P. Dean and J. Meyer, analyses of shale samples for total organic carbon with the staff of the geochemical laboratory, and stratigraphy with D. Boyce.

Regional Geologic Setting

Rocks in the study area occur in a north-south-trending belt, best exposed in the Bay of Islands, which extends northward toward the Cow Head Group and southward toward the Port au Port Peninsula (Figure 1).

The Humber Arm Group is a slice of sedimentary rocks which structurally underlies the Bay of Islands Ophiolite Complex within the Humber Arm Allochthon. The lowest components of this group are the Early(?) to Middle Cambrian Summerside and Irishtown formations, clastic units thought to be derived from the west. The carbonate- and shale-dominated Cook's Brook and Middle Arm Point formations constitute the middle part of the group and appear to span the same stratigraphic interval (Late Middle Cambrian to Early Ordovician) as the Cow Head Group to the north. The Middle Arm Point Formation passes upward into quartzofeldspathic sandstones of Late Early to Middle Ordovician age which are interpreted to be easterly-derived and herald the destruction of the carbonate margin (Stevens, 1970).

STRATIGRAPHY

Previously, only reconnaissance mapping was conducted in this area, and only two or three fossil occurrences were located prior to this study. Approximately sixty new fossil localities have been discovered in the course of this project, many of which date key parts of the section. Whereas the majority of these are graptolite localities, several important trilobite discoveries have been made. Material from three localities found in 1984 were identified by Doug Boyce. In 1985, Boyce and the author visited three key areas where trilobite debris had been noted (in boulders within limestone conglomerates) in the course of earlier mapping. Thirty-three fossiliferous boulders were collected in two days. Approximately ten other boulders were subsequently collected by the author at different localities and this material is currently being identified by Boyce. Although these discoveries reveal important stratigraphic data, their greatest significance may be in demonstrating the great abundance of trilobite material in conglomerates of the Cook's Brook Formation. This opens up the possibility of biofacies comparisons with the well-studied Cow Head Group.

SHALE GEOCHEMISTRY

The Humber Arm Group in the Bay of Islands is one of the areas examined by Dean and Meyer (1983, 1984, 1985). They carried out a program of both shale and stream sediment sampling to assess the potential of these rocks as mineral hosts, and to establish shale geochemical properties for industrial uses.

In the present study, major and trace element analyses, and determination of clay mineralogy, total organic carbon and sulfur, have been performed on approximately 160 shale samples, which span the Cook's Brook and Middle Arm Point formations and adjacent units. Preliminary results suggest marked changes in the nature of these shales through time. Cambrian and earliest Ordovician shales are relatively rich in organic carbon (3 percent) and sulfur, and appear to have been deposited under moderately reducing conditions. A dramatic change occurs at the boundary between the Cook's Brook Formation and the overlying Middle Arm Point Formation; oxidizing oceanic conditions appear to have prevailed into the Middle Ordovician. The boundary marks the onset of 1) greatly increased bioturbation, 2) silicification, 3)

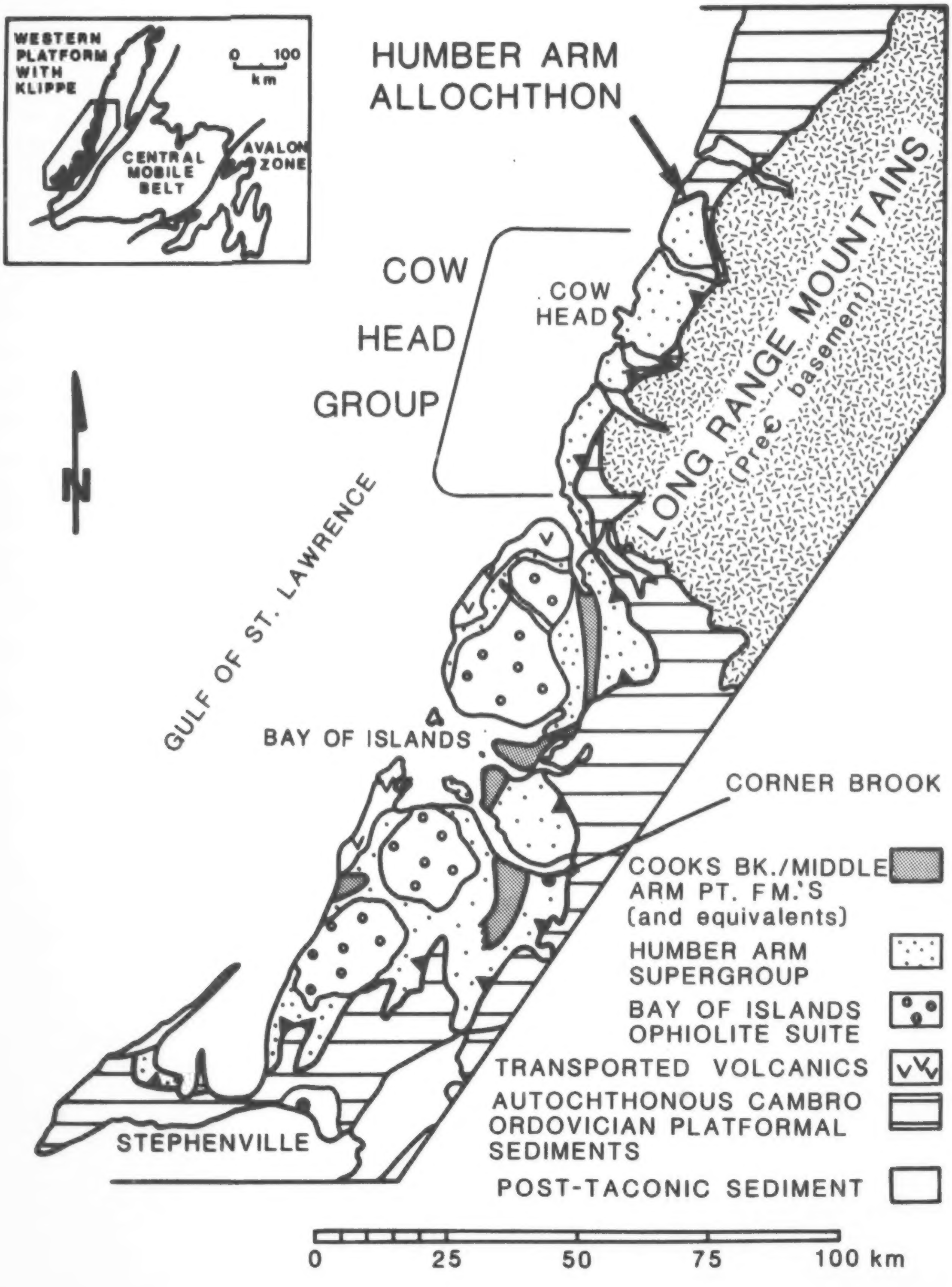
WESTERN PLATFORM WITH KLIPPE
0 100 km
CENTRAL MOBILE BELT
AVALON ZONE
HUMBER ARM ALLOCHTHON
COW HEAD GROUP
COW HEAD
LONG RANGE MOUNTAINS
(Pre€ basement)
N
GULF OF ST. LAWRENCE
BAY OF ISLANDS
CORNER BROOK
STEPHENVILLE
COOKS BK./MIDDLE ARM PT. FM.'S (and equivalents)
HUMBER ARM SUPERGROUP
BAY OF ISLANDS OPHIOLITE SUITE
TRANSPORTED VOLCANICS
AUTOCHTHONOUS CAMBRO ORDOVICIAN PLATFORMAL SEDIMENTS
POST-TACONIC SEDIMENT
0 25 50 75 100 km

Figure 1: *Regional geology of the Humber Arm Allochthon showing the distribution of the Cook's Brook and Middle Arm Point formations.*

dolomitization, 4) anomalous trace metal occurrences within shales, and 5) manganese and barite precipitation.

Shales of the Middle Arm Point Formation locally demonstrate anomalously high concentrations of manganese, which is probably related to the ambient oxidizing conditions. Manganese carbonates and oxides have precipitated within shale along discrete zones up to several centimetres thick. Several of these zones demonstrate anomalously high concentrations of lead and zinc (about 300 ppm), which may have been scavenged from seawater by the manganese crusts. Shales from several sections spanning the uppermost Middle Arm Point Formation also demonstrate anomalously high barium concentrations (up to 0.5 percent). One such sample displays authigenic barite crystals visible in hand specimen. This precipitation is also interpreted to be related to the ambient oxidizing conditions.

Base metals may be concentrated in shales of the Middle Arm Point Formation to varying degrees, and this may be responsible for some of the base metal anomalies noted in this area by Dean and Meyer (1983, 1984, 1985). Metamorphosed equivalents of these rocks have been noted in the basal aureole of the Bay of Islands Ophiolite, and may also conceivably display anomalous metal concentrations.

A preliminary examination of the shale geochemical data suggests that they may also be useful for correlation and mapping purposes; a statistical approach will be used to test this idea. When combined with the large body of data assembled by Dean and Meyer (1983, 1984, 1985), this may prove to be a useful tool in mapping structurally complex areas within the Humber Arm Allochthon. It may be possible, for example, to identify geochemical signatures in the red and green shales on Wood's Island (possibly Summerside Formation) and thus provide a great aid in sorting out the structure.

Carbon and Sulfur Analysis

Analyses for total organic carbon and sulfur can be a time-consuming and tedious process when dealing with large numbers of samples. The Infrared Carbon/Sulfur/Water Analyser used in the Newfoundland Department of Mines and Energy geochemical lab is particularly well suited to projects of this kind, since it provides simultaneous analyses for all three components (Bouvier and Abbey, 1980). Discrimination between organic carbon and 'carbonate carbon' is critical in dealing with shales; this was done in this case by analyzing acidified and non-acidified pairs of samples. A more direct approach will be investigated this winter in cooperation with Mines and Energy staff, which should provide a faster and more precise method of determining organic carbon content in sedimentary rocks.

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CONODONT COLOR VARIATION IN THE LOWER/MIDDLE ORDOVICIAN STRATA OF WESTERN NEWFOUNDLAND

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INTRODUCTION

Epstein *et al.* (1977) have demonstrated that conodont color is affected by depth and duration of burial and the geothermal gradient. The conodonts change from translucent clear to amber, brown to black, to white and clear, and the colors have been referred to indices labelled CAI (Color Alteration Index) 1 to 8. The CAI values allow an evaluation of relative thermal maturation of host rocks and give an indication of the temperatures that have affected them.

CAI values have economic significance because they can be compared with other organic maturity indices such as vitrinite reflectance and palynomorph translucency (Epstein *et al.*, 1977). CAI values allow the evaluation of oil potential of carbonate terranes in which organic material normally is sparse. Epstein *et al.* (1977) showed that CAI values within 1 to 2 are characteristic of oil-producing areas, CAI values up to 4 typify gas-producing areas, whereas CAI values higher than 4 are typical of nonproductive areas.

WESTERN NEWFOUNDLAND CONODONTS

Conodont collections from western Newfoundland show considerable color variation from pale amber to black, and the data available from Ordovician strata allow for a preliminary investigation of thermal trends. The map (Figure 1) indicates the distribution of CAI values recognized in western Newfoundland, based on numerous conodont collections retrieved from single sample localities and from thick lithostratigraphic sections.

The color of conodonts can be affected by superficial staining or infilling of the basal cavity with organic material. Therefore, several samples were examined in each section; only one sample was examined in single, widely spread collections. Color also varies with the structure and robustness of the elements, thus comparison was based on forms that are abundant in the majority of sections, principally elements of *Parapanderodus*, *Periodon*, *Diaphorodus* and *Oepikodus*.

The CAI values (Figure 1) reveal amber coloration (CAI 1 to 1½) in the Port au Port-Cow Head area and the region north of Cow Head. There is increasing thermal maturation northward to Cape Norman and eastward to Hare Bay and Canada Bay. Here the lower Paleozoic succession is moderately deformed and is marginal to the Taconic Hare Bay Allochthon. Black coloration of elements occurs at Serpentine Lake and in the Corner Brook and Bonne Bay regions. This area is also deformed and metamorphosed and is marginal to the Humber Arm Allochthon. Black coloring occurs east of Cape Norman in Pistolet Bay, Hare Bay and Canada Bay. CAI values of 5 to 6 are recorded from Ordovician limestones in White Bay and from limestones within the White Arm Window of the Hare Bay Allochthon. The black coloration of elements (some have a gray tint) in these areas, suggest maximum temperatures in excess of 300°C. In central Newfoundland, the CAI values are 5 and higher (Stouge 1980, 1984).

Figure 1 indicates that the best potential for oil or gas production is in the Port au Port-Cow Head area, and in the region north of Cow Head to about 100 km south of Cape Norman. A narrow belt southward from Cape Norman defines the limit for potential gas production. East of this belt, defined by the CAI 4 isotherm, higher CAI values occur.

The trend of increasing high values conforms with the trend of the allochthonous rocks (Stouge, 1984) in Pistolet Bay and Hare Bay-Canada Bay. In Bonne Bay, the change from low values to high is sharp (Figure 1). The increase of CAI values toward Cape Norman is inverted in relation to the stratigraphy, because the Boat Harbour Formation has lower values than the younger Catoche Formation. This is probably a reflection of the increasing deformational intensity eastward in this area. The high CAI values of rocks in the Humber Arm region likely reflects similar increasing eastward deformation and also burial beneath the Bay of Islands ophiolite.

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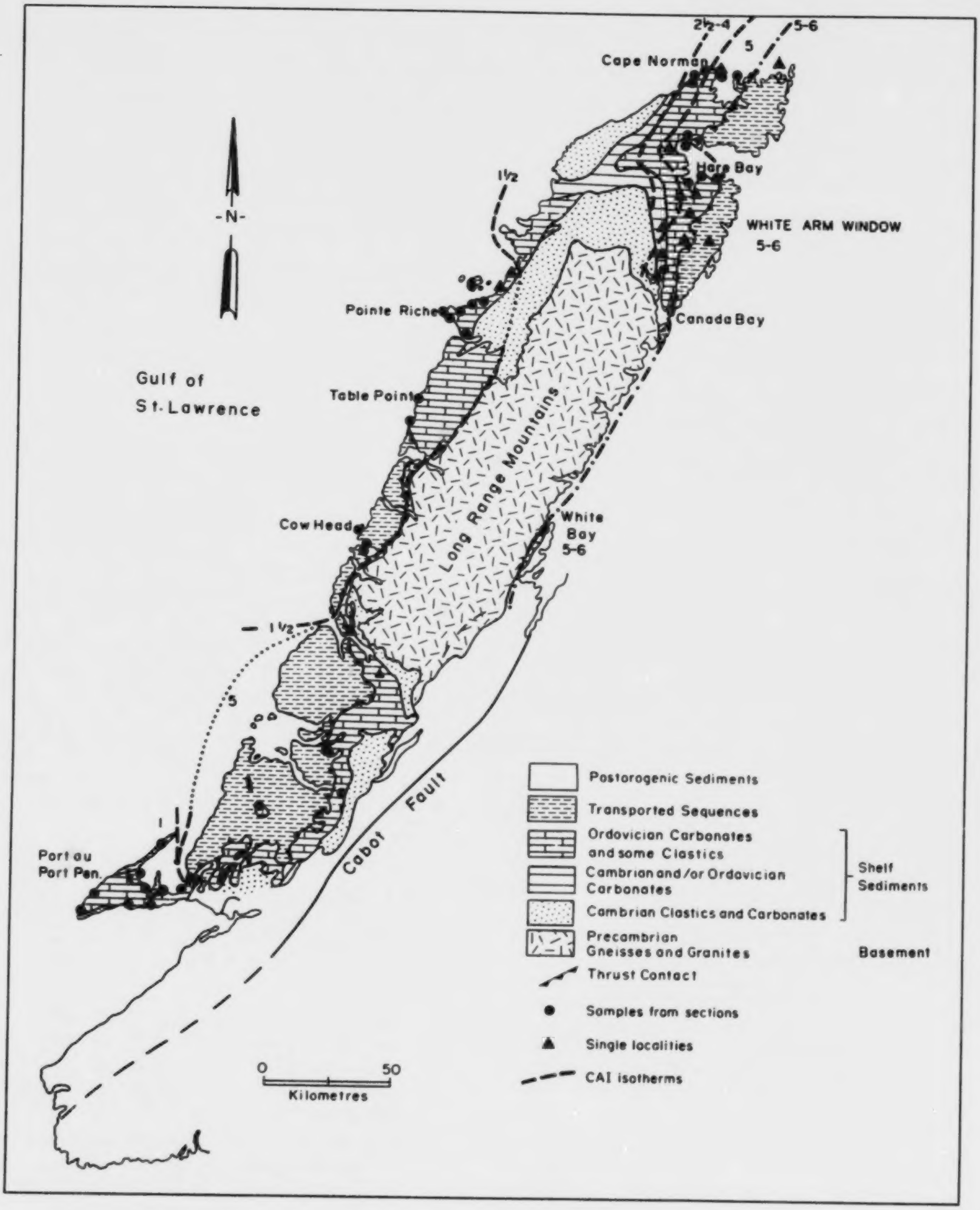
2½-4
5
5-6
Cape Norman
Hare Bay
WHITE ARM WINDOW
5-6
1½
-N-
Pointe Riche
Canada Bay
Gulf of
St. Lawrence
Table Point
Long Range Mountains
Cow Head
White
Bay
5-6
1½
5
1
Port au
Port Pen.
Cabot Fault
Postorogenic Sediments
Transported Sequences
Ordovician Carbonates and some Clastics
Cambrian and/or Ordovician Carbonates
Cambrian Clastics and Carbonates
Shelf Sediments
Precambrian Gneisses and Granites
Basement
Thrust Contact
Samples from sections
Single localities
CAI isotherms
0
50
Kilometres

Figure 1: *Conodont Color Alteration Index (CAI) isotherm map for western Newfoundland (data from Stouge, 1980, 1982, 1984 and unpublished).*

Current Research (1986) Newfoundland Department of Mines and Energy
Mineral Development Division, Report 86-1, pages 179-188

GEOLOGY OF THE EAST PART OF THE SNOWSHOE POND (12A/7) AREA

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Newfoundland Mapping Section

ABSTRACT

The eastern third of the Snowshoe Pond (12A/7) map area has been mapped at a scale of 1:50,000. It is divided into two parts by Noel Paul's Line, a tectonic and/or intrusive contact which passes southeast of Lake Douglas. Southeast of the line, stratified rocks consist of a single unit of polyphase-deformed clastic metasedimentary rocks, metamorphosed in the upper amphibolite facies. These rocks are interpreted to be equivalent to the Middle Ordovician Spruce Brook Formation. They have been intruded by a series of mafic dikes. Northwest of Noel Paul's Line, there is a succession of metavolcanic and metasedimentary rocks similar to the Lower to Middle Ordovician rocks typical of the Central Volcanic Belt. They are metamorphosed in the greenschist facies and are polydeformed. Deformation is most intense adjacent to their southeastern boundary.

Granitoid intrusions are of three main types. The earliest is equigranular biotite granite containing a folded foliation; it is in intrusive contact with the metasedimentary rocks southeast of Noel Paul's Line and is in either intrusive or tectonic contact with the metasedimentary rocks to the north of the line. Several phases of granite/granodiorite of the North Bay Granite have intruded the foliated granite and the southeastern metasedimentary rocks posttectonically. A small granite pluton that postdates at least part of the deformation truncates Noel Paul's Line.

The potential mineral deposits in the area are of three main types: 1) tungsten mineralization associated with the granitoid intrusions; 2) volcanogenic base and precious metal deposits in rocks of the Central Volcanic Belt, northwest of Noel Paul's Line; 3) gold mineralization associated with major tectonic lineaments that are marked by probable ophiolitic rocks outside the area. No major showings of economically exploitable minerals have yet been discovered.

INTRODUCTION

The Snowshoe Pond (12A/7) map area is located about 40 km south of Buchans in the centre of the Newfoundland Central Mobile Belt (Williams, 1964). It is accessible from Millertown by the hydro roads to Granite Lake and Ebbegunbaeg dam. Mapping at the 1:50,000 scale has been completed in the eastern one third of the map area (Figure 1).

The northwestern part of the area is underlain by Lower Paleozoic volcanic and sedimentary rocks (Units 3 to 10) typical of the Dunnage Zone (Williams, 1978), and is included in the Central Volcanic Belt of Kean *et al.* (1981). In the southeastern part of the area, the oldest rocks (Unit 1) are high grade, clastic, metasedimentary rocks, resembling the Middle Ordovician Spruce Brook Formation of Colman-Sadd and Swinden (1984). These rocks are intruded by several granitoids, one of which (Unit 18) intrudes rocks of the Central Volcanic Belt. The contact between the Central Volcanic Belt and the metamorphic and intrusive rocks to the southeast was referred to as Noel Paul's Line by Brown and Colman-Sadd (1976); this may coincide with the lineament proposed as the Iapetus suture by McKerrow and Cocks (1977). Kean and Jayasinghe (1980) and Dallmeyer *et al.* (1983) placed Noel Paul's Line along an assumed fault at the southeast edge of the Rogerson Lake Conglomerate (Unit 10), and they described the transition to the high grade metamorphic rocks of Unit 1 as gradational. In the eastern part of the Snowshoe Pond area, southeast of the Rogerson Lake Conglomerate, Units 3 to 9, are considered to be similar to the Victoria Lake Group of the Central Volcanic Belt and distinct from Unit 1. Noel Paul's Line is therefore drawn along the contact between Unit 3 and granite of Unit 11, but it remains uncertain as to whether this contact is intrusive or tectonic.

The earliest geological investigations in the Snowshoe Pond area were those of Cormack (1823), during his walk across the island of Newfoundland, and Howley (1917), when he led an expedition from Bay d'Espoir to the Exploits River in 1887.

Further work was done in the early 1950's by the Buchans Mining Company, and compiled by Swanson (1952-60). Williams (1970) produced a 1:250,000 scale map of Red Indian Lake (east half) for the Geological Survey of Canada and this includes the geology of the Snowshoe Pond area. Work by the Newfoundland Department of Mines and Energy consists of a lake sediment geochemistry survey (Butler and Davenport, 1978; Davenport and Butler, 1981) and surficial geology studies (Sparkes, 1984). Geological mapping by the department at the 1:50,000 scale has been done in neighbouring map areas (Colman-Sadd, 1985; Dickson, 1982; Dickson and Delaney, 1984; Kean, 1977; Kean and Jayasinghe, 1980).

Recent exploration by mining companies, in the part of the Snowshoe Pond area shown in Figure 1, has concentrated

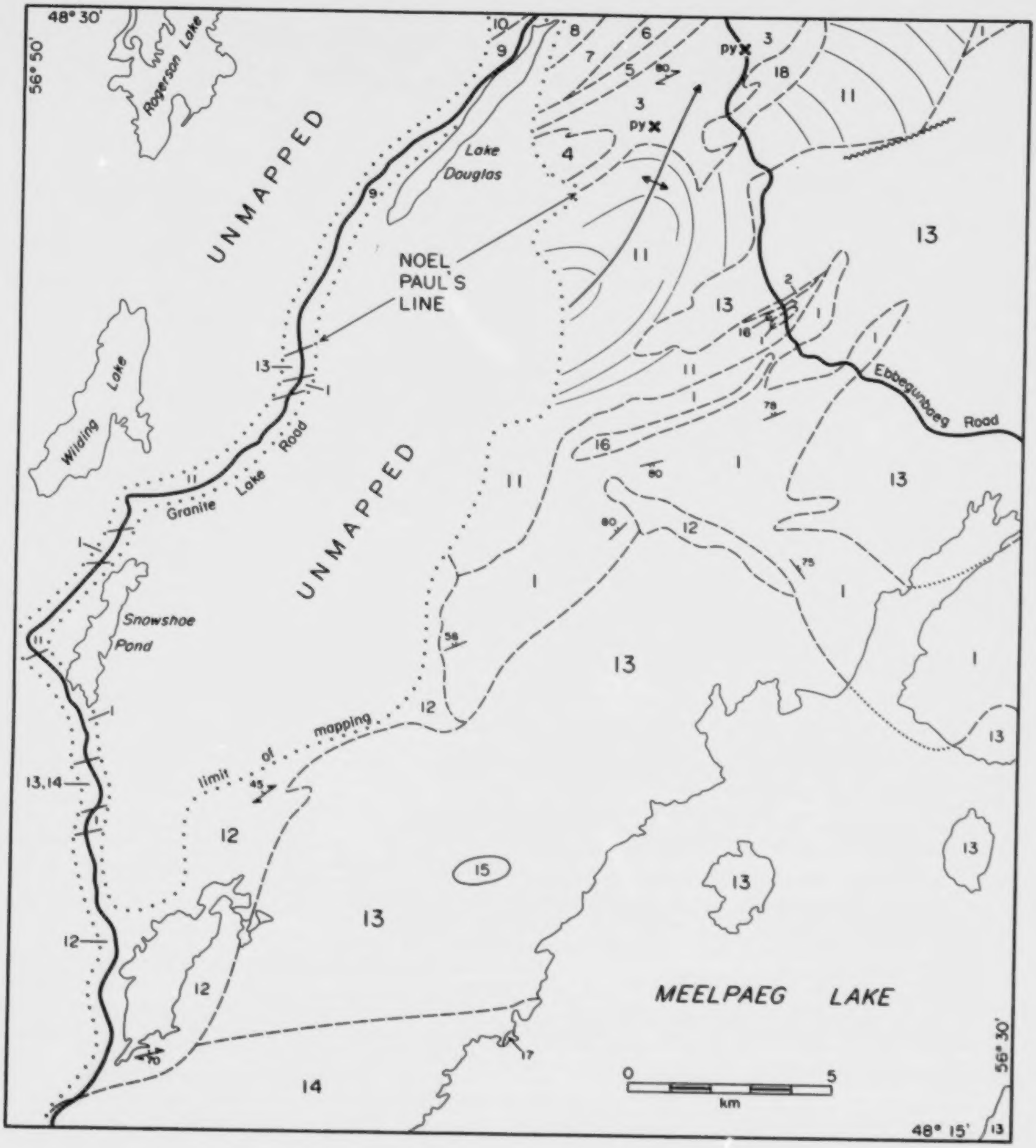
48° 30'
56° 50'
Rogerson Lake
UNMAPPED
Lake Douglas
NOEL PAUL'S LINE
Wilding Lake
Granite Lake Road
Snowshoe Pond
UNMAPPED
limit of mapping
Ebbegunbaeg Road
py
MEELPAEG LAKE
56° 30'
48° 15'
0
5
km
1
2
3
4
5
6
7
8
9
10
11
12
13
13,14
14
15
16
18

Figure 1: *Geological sketch map of the eastern part of the Snowshoe Pond (12A/7) map area.*

LEGEND

SILURO-DEVONIAN	
18	Equigranular, medium grained, white, muscovite-biotite granite.
17	Equigranular, medium-fine grained, pink syenite(?).
16	Garnet-tourmaline-muscovite pegmatite.
NORTH BAY GRANITE (Units 13-15)	
15	Equigranular, medium grained, white, muscovite-garnet granite (not exposed *in situ).*
14	Equigranular, medium grained, gray to buff, biotite-muscovite granodiorite.
13	Porphyritic to equigranular, medium grained, gray to pink, biotite granodiorite.
12	Migmatite, rich in biotite schlieren and metasedimentary fragments derived from Unit 1. Gradational into Unit 13 of the North Bay Granite.
11	Equigranular, foliated, medium grained, gray to pink, biotite granite. Locally mylonitic.
SILURIAN ?	
10	Rogerson Lake Conglomerate: purple, clast-supported, polymictic conglomerate and sandstone.
ORDOVICIAN	
9	Thinly bedded, brown, gray to green siltstone and shale with minor mafic volcanic rocks.
8	Gray, foliated to massive, felsic crystal tuff and/or felsic flows and/or subvolcanic intrusive rocks.
7	Unseparated black phyllite and gray, foliated, felsic crystal tuff.
6	Conglomerate formed mainly of subrounded felsic volcanic clasts, interbedded with black phyllite.
5	Gray foliated felsic crystal tuff.
4	Very well cleaved, polydeformed, gray, fine grained, felsic tuff and/or rhyolite.
3	Very well cleaved, polydeformed, sericitic schist, black pyritic schist and fine grained felsic volcanic rocks.
2	Foliated, fine grained, amphibolite, probably derived from mafic dikes intrusive into Unit 1.
1	Interbedded quartzite, psammite, semipelite and pelite, intruded by unseparated mafic dikes; polydeformed and mainly metamorphosed at sillimanite grade (probably equivalent to Spruce Brook Formation).

on two targets. Tungsten mineralization was discovered in the Wolf Mountain (12A/2) area to the south during follow up of lake sediment geochemical anomalies (Butler and Davenport, 1978; Dickson and MacLellan, 1981), and a number of claims related to this discovery extended onto the southern edge of the Snowshoe Pond map area (Godfrey and Lane, 1981; Neelands, 1980; Saunders, 1980a,b). Noranda Exploration Company and Price Newfoundland Company have explored rocks of the Central Volcanic Belt in the northwestern parts of the Snowshoe Pond map area under the Price-Norex Joint Venture. Some of their reports concern the area mapped in 1985, but all of these are presently confidential (Aerodat, 1983; Fitzpatrick, 1984a,b, 1985).

GENERAL GEOLOGY

The stratified rocks of the Snowshoe Pond map area are divided into the single unit of monotonous clastic metasedimentary rocks (Unit 1) to the southeast of Noel Paul's Line, and the eight units of very variable metasedimentary and metavolcanic rocks (Units 3 to 10) to the north of the line. Amphibolite (Unit 2), which at least in some cases represents mafic dikes, is widespread in the southeast, but is not volumetrically important; it may or may not be related to unseparated mafic flows, tuffs and dikes in the other units.

Metamorphic grade northwest of Noel Paul's Line is principally in the greenschist facies, although a few restricted areas may be in the lower amphibolite facies. To the southeast of the line, metasedimentary rocks of Unit 1 are mostly at sillimanite grade (upper amphibolite facies).

The granitoid rocks fall into three main groups:

1) the pretectonic biotite granite (Unit 11) that intrudes Unit 1 and is in either intrusive or tectonic contact with Unit 3 along Noel Paul's Line

2) the largely posttectonic biotite and biotite-muscovite granodiorite (Units 13 and 14) of the North Bay Granite with associated migmatite (Unit 12), muscovite-garnet granite (Unit 15) and pegmatite (Unit 16)

3) the syn to posttectonic leucogranite of Unit 18 that has intruded the units on either side of Noel Paul's Line.

Metasedimentary Rocks (Unit 1)

The rocks of Unit 1 are a direct continuation of a metasedimentary unit that extends eastwards across the Great Burnt Lake (12A/8) map area to the western edge of the Great Burnt Lake volcanic belt (Colman-Sadd and Swinden, 1982; Colman-Sadd, 1985). This unit is equated with the Middle Ordovician Spruce Brook Formation of Colman-Sadd and Swinden (1984), which occurs on the east side of the Great Burnt Lake volcanic belt, and with which it is not in direct contact. A similar correlation was made by Higgins (1951).

Unit 1 consists of interbedded quartzite, psammite, semipelite and pelite (Plate 1). Bed thickness varies from 3 cm to over 1 m and the proportions of the rock types are also quite variable. Overall, quartzite and psammite each form between 15 and 25 percent of the whole. The quartzite is light gray on fresh surfaces, but weathers white. Its grain size is 2 mm or less and generally fairly uniform. Beds commonly have sharp bases and laminated more micaceous upper sections. The psammite is dark gray and weathers brown, reflecting its greater mica content. Bed contacts are sharp but internal sedimentary structures are not prominent. The semipelite and pelite are dark gray or black and are locally rich in pyrite and/or tourmaline. They are generally faintly laminated and have thin interbeds of cross laminated psammite and quartzite. In some exposures, the semipelite has myriads of bedding-parallel quartz segregations.

Two main periods of deformation have affected the rocks of Unit 1. The first formed a ubiquitous cleavage in the micaceous beds which is commonly, but not exclusively, parallel to bedding. In the quartzite beds, either there is no mesoscopic cleavage, or there is a micaceous parting, spaced 0.5 to 2 cm apart; a similar fabric is interpreted as a spaced cleavage in the Great Burnt Lake (12A/8) map area (Colman-Sadd, 1985). This interpretation relies on the observation that the cleavage is discordant to bedding in first deformation fold hinges; however, no such occurrences were observed in the Snowshoe Pond area. The second deformation formed tight to isoclinal folds of bedding, the first cleavage, and migmatitic sweats. The folds are very common in some localities, for example in the northern inlet of Meelpaeg Lake, and rarely developed in others. A slight to moderate crenulation cleavage was formed during the second deformation in a few places, but is nowhere very prominent.

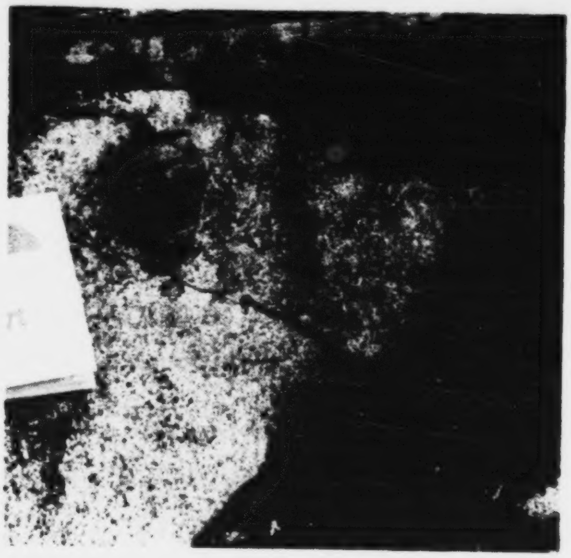

Plate 1: *Interbedded quartzite and sillimanite schist (Unit 1), intruded by biotite granodiorite (Unit 13), north shore of Meelpaeg Lake.*

Most of Unit 1 was metamorphosed at sillimanite grade and 2 to 5 mm aggregates of fibrolite are common features in the semipelitic and pelitic beds. Between the outcrops of foliated granite (Unit 11) and pegmatite (Unit 16), Unit 1 is probably of lower grade and contains porphyroblasts of possible andalusite and staurolite. Much of Unit 1 is migmatitic, due in part, to the injection of sheets of granite or granodiorite (Plate 1). However, in many places there has been *in situ* melting, resulting in a complete range from small, isolated granitic segregations to migmatitic gneiss and granitoid containing metasedimentary xenoliths.

The timing of metamorphism relative to structural development is uncertain at present because the relationship between cleavage and fibrolite aggregates is difficult to determine in the field. However, there are strong indications from the relationship of structures to migmatization that the peak of metamorphism postdated the first deformation and predated the second. Granitoid veins crosscut the main cleavage and have been folded by the second generation folds. Also the North Bay Granite (Units 13 to 15), which has a close spatial relationship to the highest grade metamorphic rocks (Colman-Sadd, 1985), contains many prefoliated xenoliths of Unit 1.

Amphibolite (Unit 2)

The amphibolite of Unit 2 is generally a fine grained dark green rock containing a single well developed foliation. In a few isolated localities, unfoliated medium grained gabbro occurs, but its relationship to the other rock units was not determined. The only outcrop area of amphibolite or gabbro that is sufficiently large to be separated on the map occurs on the Ebbegunbaeg road. It consists of foliated fine grained amphibolite and is intruded by foliated and unfoliated granite veins. Elsewhere, particularly in the northern inlet of Meelpaeg Lake, amphibolite has formed by the metamorphism of mafic dikes that have intruded metasedimentary rocks of Unit 1. In one exposure, the foliation in the amphibolite is continuous with the first cleavage in Unit 1. A first deformation fold in the dike is cut by a granite vein related to the North Bay Granite; the granite vein itself was folded during the second deformation.

Polydeformed Schist and Metavolcanic Beds (Unit 3)

Unit 3 consists of a variety of metasedimentary and metavolcanic rock types, interlayered on a scale of 2 cm to 2 m, and all intensely deformed. It occurs as the southeasternmost unit of the Central Volcanic Belt, adjacent to foliated granite of Unit 11, and is well exposed along the northern part of the Ebbegunbaeg road.

The dominant rock type of Unit 3 is light greenish-gray sericitic schist, commonly containing disseminated pyrite and amphibole. The sericitic schist grades into zones of gray to black pyritic schist which locally includes bands of massive pyrite and pyrrhotite up to 3 cm thick and 2 m long. Interlayered with the schist is a fine grained, white, pyritic, quartzofeldspathic rock, interpreted as felsic tuff, and a few occurrences of foliated fine grained amphibolite.

Plate 2: *Composite shear and flattening fabric in sericitic schist (Unit 3), Ebbegunbaeg road.*

The schist has a first deformation composite foliation, consisting of shear(C) and flattening(S) fabrics that have destroyed all fine sedimentary structures in the original rock (Plate 2). The C fabric planes have a spacing of 0.5 to 1 mm and are marked by a metamorphic differentiation between the micas and quartz and feldspar. The white quartzofeldspathic layers have a single first deformation foliation containing a very pronounced stretching lineation on cleavage surfaces (Plate 3). The second deformation has formed tight folds of the layering, the first fabrics, and numerous quartz segregations. The folds plunge gently to the northeast and their axes make angles of about 70° with the first deformation lineation. A crenulation cleavage, formed during the second deformation, is present in the schist layers.

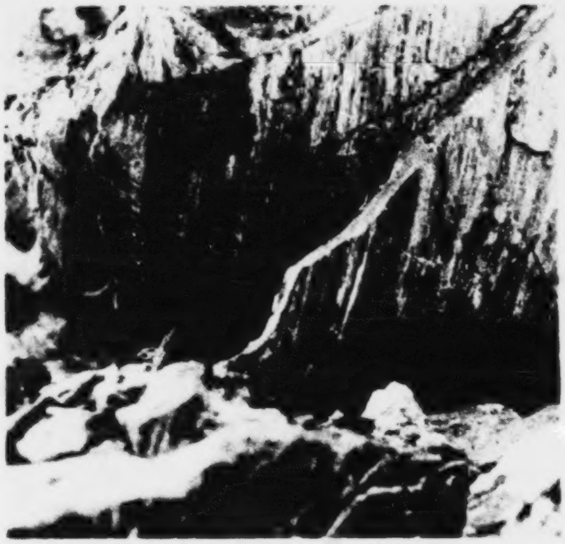

Plate 3: *Stretching lineation on cleavage surface of quartzofeldspathic layer in Unit 3, Ebbegunbaeg road. Note curvature of lineation around F_2 fold hinge in bottom left of photograph.*

Felsic Metavolcanic Rocks (Unit 4)

Felsic interbeds of Unit 3 thicken and become the dominant rock type in one area east of Lake Douglas, where they are separated as Unit 4. The well-cleaved, fine grained, light gray to white, quartzofeldspathic rock is generally featureless. However, near the northwestern edge of the outcrop area, where deformation is less intense, quartz and feldspar crystals and flattened pumice fragments are visible in a few exposures.

Felsic Crystal Tuff (Unit 5)

Unit 5 forms a narrow outcrop area bordering the northwestern boundary of Unit 3. It consists of a dark gray crystal-lithic tuff, in which the crystals are either all feldspar or feldspar and quartz. It also contains minor amounts of disseminated sulfide minerals. The tuff has a penetrative first deformation cleavage, but is not nearly as deformed as the rocks of Units 3 and 4, and has negligible second deformation structures.

Conglomerate (Unit 6)

Conglomerate (Unit 6) lies just northwest of Unit 5. Clasts consist mainly of flow-banded rhyolite, crystal tuff and indeterminate felsic volcanic rocks. They are up to 30 cm in length and are flattened, with an approximate length to width ratio of 3:1, in a plane that is slightly oblique to the cleavage. The clasts are subangular and the conglomerate is clast supported. Lenses and interbeds of black slate occur in a few places. The rock has a single cleavage, and associated tight to isoclinal folds occur in quartz veins.

Unseparated Phyllite and Felsic Tuff (Unit 7)

Unit 7 consists of interbedded gray to black phyllite, felsic lapilli tuff and sericitic schist. All the rock types have a single penetrative cleavage.

Felsic Igneous Rocks (Unit 8)

Unit 8, which forms the two large hills just east of Lake Douglas, contrasts with neighbouring units in its homogeneity. It consists of gray, fine grained, felsic igneous rocks, locally containing quartz crystals. Either a fracture cleavage or a weak penetrative cleavage is developed. It is, at present, uncertain whether the unit represents tuff, flows or a subvolcanic intrusion.

Siltstone, Shale and Mafic Volcanic Rocks (Unit 9)

Unit 9 is exposed along the Granite Lake road and is not in direct contact with Unit 8. It consists principally of laminated brown weathering siltstone and gray to green shale containing a few beds of arkosic sandstone. Bed thickness is between 1 and 5 cm. At the north edge of the map area, the sedimentary rocks, which are exclusively green at this locality, are interbedded with pyritiferous, silicified, mafic volcanic rocks. The first deformation formed a weakly penetrative or fracture cleavage in the siltstones and shales, and disrupted bedding and laminae near fold hinges. Second deformation structures consist of crenulations and, in one locality, a weak crenulation cleavage. Rocks to the northwest of Unit 8, around the shores of Lake Douglas, have not yet been mapped.

Rogerson Lake Conglomerate (Unit 10)

The Rogerson Lake Conglomerate is the continuation of a formation mapped to the northeast in the Lake Ambrose (12A/10) and Noel Paul's Brook (12A/9) map areas by Kean and Jayasinghe (1980). It extends across the Snowshoe Pond map area (Williams, 1970). The only exposure examined during this study occurs on an island in Louis Lake.

The conglomerate consists of subrounded clasts, 1 mm to 2 cm across, of chert, felsic and mafic volcanic rock, red shale and vein quartz. It is poorly sorted and clast supported. Massive sandstone is gradational with the conglomerate, but the contacts are not sufficiently distinct to give a clear indication of bedding. The conglomerate and sandstone are light purple. A moderate cleavage is developed and is openly folded by a second period of deformation.

Foliated Biotite Granite (Unit 11)

Unit 11 consists of pink or gray, equigranular, medium grained, biotite granite. In most exposures, the biotite defines an anastomosing planar fabric, spaced 2 mm to 10 cm apart (Plate 4). A stretching lineation is also defined by mica, feldspar and quartz on cleavage surfaces. In some zones, most notably on the Granite Lake road, west of Snowshoe Pond, the fabric is mylonitic and the granite is reduced to a schist (Plate 5). The granite also erodes as a series of ridges (Plate 6) controlled by the first deformation fabric, and these ridges clearly define large-scale, second deformation folds (Plate 7). The folds have wavelengths in the order of 2 km and plunge gently to the northeast. The curved contact of the granite with Unit 3, west of the Ebbegunbaeg road, defines the hinge of an antiform, and the folds in the granite correspond to the smaller second deformation folds in Unit 3.

The foliated granite has an intrusive contact with clastic metasedimentary rocks of Unit 1. The contact is exposed on the Ebbegunbaeg road and there is continuity between the first deformation fabrics in the two units. There does not appear to be any increase in metamorphism toward the granite, but if there was originally an aureole, it is likely to be obscured by the subsequent posttectonic metamorphism associated with the North Bay Granite.

The contact between the granite and Unit 3 represents Noel Paul's Line as envisaged by Brown and Colman-Sadd (1976). However, the nature of the contact remains uncertain because of lack of exposure. As noted above, the contact follows the outline of a second deformation fold, and thus appears to have been folded. There may be a slight increase in the metamorphism of Unit 3 toward the granite, but the most prominent feature is the intense deformation of Units 3 and 4, compared with the rocks to the northwest. This focus of deformation is not reflected in the granite, which is less deformed along its northwestern edge than in the mylonite zones in its interior. The choice of origin for Noel Paul's Line lies between an intrusive contact which has been modified by faulting and subsequent folding, and a folded fault contact.

Migmatitic Gneiss (Unit 12)

Migmatitic gneiss (Unit 12) is distinguished from partially melted metasedimentary rocks of Unit 1 by the absence of sedimentary layering. There is, in fact, a gradation from Unit 1 metasedimentary rocks into migmatitic gneiss which, in turn, grades into granodiorite of the North Bay Granite.

The migmatitic gneiss consists of an equigranular, medium grained, biotite-muscovite granite leucosome, and varying proportions of biotite-rich schlieren. There are also xenoliths of psammite and quartzite. The foliation in the gneiss is defined by a preferred orientation of the schlieren, but there is no tectonic fabric within the granite leucosome. The gneiss is commonly cut by muscovite-garnet aplite and pegmatite veins.

North Bay Granite (Units 13, 14 and 15)

Two lobes of the North Bay Granite extend westward from the Great Burnt Lake (12A/8) map area (Colman-Sadd,

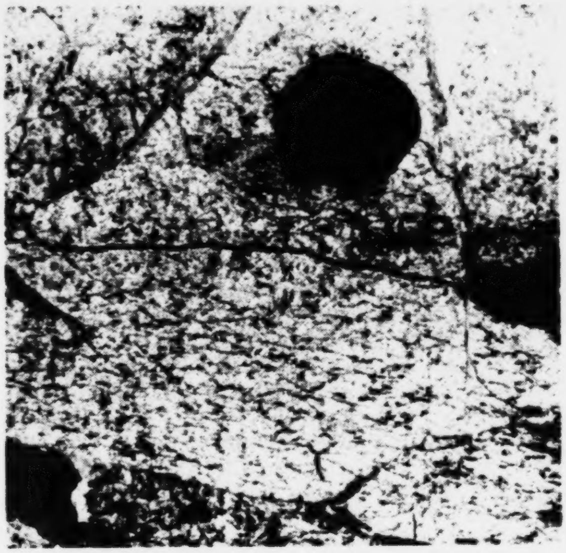

Plate 4: *Foliation in equigranular, biotite granite (Unit 11), Ebbegunbaeg road.*

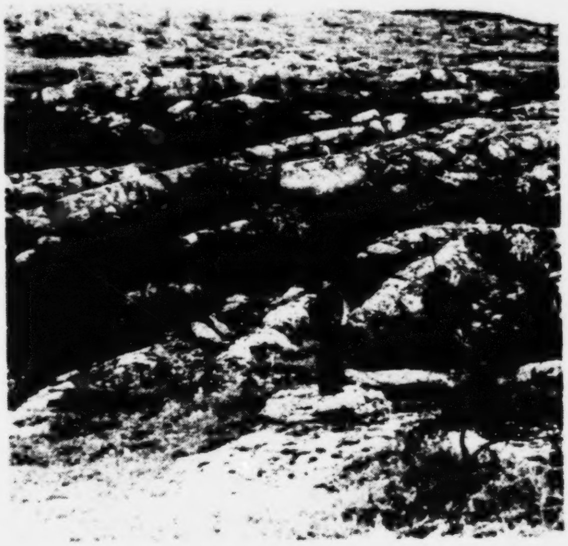

Plate 6: *Foliation-controlled ridges of equigranular biotite granite (Unit 11), west of Ebbegunbaeg road. The ridges define the F_2 fold shown in Plate 7.*

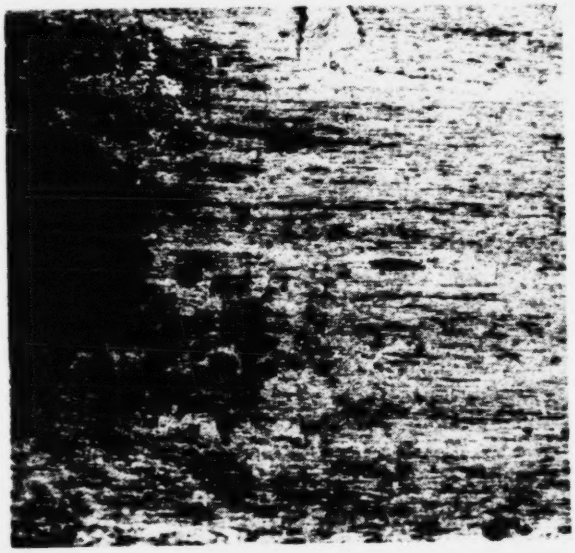

Plate 5: *Mylonitized granite (Unit 11), Granite Lake road.*

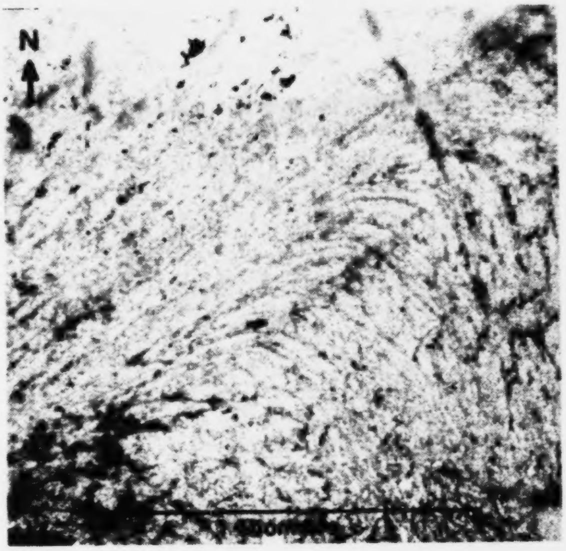

Plate 7: *Aerial photograph showing major F_2 fold, plunging gently to the northeast, in foliated, equigranular, biotite granite (Unit 11), west of Ebbegunbaeg road.*

1985), and the southern one continues southward into the Wolf Mountain (12A/2) map area (Dickson, 1982; Dickson and Delaney, 1984). The principal rock type in the Snowshoe Pond area is medium to coarse grained, gray to pink, porphyritic, biotite granodiorite (Unit 13). The potassium feldspar phenocrysts are locally absent in the interior parts of the granodiorite and are not developed where the granodiorite grades into migmatite (Unit 12). In some localities on the north and east shores of Meelpaeg Lake, the phenocrysts are concentrated in crude layers, which are associated with concentrations of xenoliths. The xenoliths consist mainly of quartzite, psammite and biotite-sillimanite schist similar to rock types in Unit 1. They are generally planar and aligned (Plate 8), and are accompanied by round to elliptical inclusions of either biotite-hornblende microgranitoid or diorite.

Plate 8: *Foliated metasedimentary xenoliths, probably derived from Unit 1, in porphyritic biotite granodiorite of the North Bay Granite (Unit 13), southeast Meelpaeg Lake.*

Unit 14 is exposed on the Granite Lake road and is interpreted, from boulder distribution, to underlie the southern part of the map area between the road and the west shore of Meelpaeg Lake. It consists of gray to buff, medium grained, equigranular, biotite-muscovite granite. It contains the same types of xenoliths as the granodiorite, but its relationship to the granodiorite is uncertain.

Unit 15 is not exposed in the Snowshoe Pond area, but its presence is indicated by a concentration of boulders just west of Meelpaeg Lake. It consists of medium-fine grained, equigranular, garnet-muscovite granite, and is similar to a phase of the North Bay Granite exposed on the Ebbegunbaeg road in the Great Burnt Lake (12A/8) map area (Colman-Sadd, 1985).

All three units of the North Bay Granite are cut by garnet-tourmaline-muscovite granite pegmatites and aplites. All three are also essentially posttectonic. Although a weak fabric defined by stretched quartz and aligned biotite occurs at the northwestern edge of the granodiorite outcrop area, the intrusion appears to transect one limb of the fold in the foliated granite of Unit 11 and so was probably emplaced in the terminal stages of the second deformation. Foliated xenoliths of Unit 11 occur in the granodiorite at the contact on the Ebbegunbaeg road, and foliated xenoliths of Unit 1 metasedimentary rocks are ubiquitous.

Pegmatite (Unit 16)

Very coarse grained, garnet-muscovite granite pegmatite, containing feldspar crystals up to 30 cm long, occurs in a string of exposures southwest of the Ebbegunbaeg road. They are interpreted to form a single intrusion. A similar pegmatite intrusion, but also containing tourmaline, occurs on the road 1 km to the north, and is probably a separate intrusion. Both intrusions are posttectonic and may be related to the North Bay Granite.

Syenite(?) (Unit 17)

Syenite(?) of Unit 17 occurs in a single exposure on the west shore of Meelpaeg Lake in an area that is generally poorly exposed, but is thought to be underlain mostly by granite and granodiorite of Units 13 and 14. The syenite is pink, medium-fine grained, and equigranular, except for a few feldspar phenocrysts. It is composed of pink and white feldspar, green chlorite and/or hornblende, and accessory pyrite. It contains scattered, pink, aphanitic rock fragments. Its relationship to other units is unknown.

Leucogranite (Unit 18)

Unit 18 consists of white, medium grained, equigranular leucogranite. It consists of quartz, white feldspar and minor amounts of biotite, chlorite and muscovite, and is cut by quartz and quartz-tourmaline veins.

The granite appears from its outcrop pattern to be intrusive into the polydeformed schists of Unit 3, but no contacts are exposed. Its contact with the foliated granite of Unit 11 consists of a zone about 1 km wide in which sills of leucogranite have intruded parallel to the cleavage surfaces in the foliated granite. The leucogranite is brecciated and has a fracture cleavage, but it is no more deformed where it intrudes mylonite than where it intrudes moderately foliated granite. It is therefore considered to postdate the first mylonitic deformation, but it may have been involved in at least part of the second deformation. Its age relationship relative to the North Bay Granite is uncertain.

MINERAL POTENTIAL

Three types of mineralization are likely to occur in the rocks of the eastern part of the Snowshoe Pond area.

Tungsten Mineralization

Wolframite, scheelite, molybdenite and pyrite are present in quartz veins and as disseminations on joint surfaces in the granitoid rocks of the North Bay Granite in the Wolf Mountain (12A/2) map area (Dickson, 1982). Although no occurrences have been found in the Snowshoe Pond area, the nearest showings are only 1 km to the south, and lake sediment anomalies in Cu, Pb, Zn, Mo, Ag, U and F extend across the southern edge of the map area (Butler and Davenport, 1978; Davenport and Butler, 1981). The lack of exposure makes it unlikely that any mineralization would be apparent at the surface in the area examined so far.

Volcanogenic Base and Precious Metal Mineralization

Felsic volcanic rocks of Units 3 to 8 and mafic volcanic rocks in Unit 9 are characteristic of the Central Volcanic Belt of the Dunnage Zone (Kean *et al.*, 1981). They are probably of Lower to Middle Ordovician age and equivalent to the Victoria Lake Group (Kean, 1977) and the pre-Caradocian island arc sequences of Dean (1978). Such correlations suggest the possibility of massive sulfide deposits such as those occurring in the Tally Pond and Tulks Hill volcanic belts (Swinden and Thorpe, 1984). Disseminations and thin layers of pyrite and pyrrhotite were found in Unit 3 and a chalcopyrite occurrence was reported along strike to the northeast by Kean and Jayasinghe (1980).

Lineament-related Gold Mineralization

Two major lineaments pass through the northwestern part of the area. The first is Noel Paul's Line where the Central Volcanic Belt abuts against foliated granite of Unit 11, and the second is the assumed fault contact between the Rogerson Lake Conglomerate (Unit 10) and the volcanic and sedimentary rocks to the southeast of it (Kean and Jayasinghe, 1980). Northeastward along the strike of the second lineament is the Pine Falls Formation, which may be ophiolitic. Tuach and French, (*this volume*) discuss the association of gold mineralization with ophiolite-lined lineaments (Albers, 1981) and include the Noel Paul's Line/Pine Falls Formation lineaments on their Figure 1. So far, no indications of gold mineralization have yet been found and reconnaissance sampling along the Ebbegunbaeg road has failed to produce significant assay values. The geological setting does, however, suggest above average potential and more detailed work may be worthwhile.

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GEOLOGY OF THE CENTRAL PORTION OF THE HERMITAGE FLEXURE AREA, NEWFOUNDLAND

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ABSTRACT

The oldest known rocks in the region are pre-Middle Ordovician mafic meta-igneous complexes, representing vestiges of either the crust of an ocean basin or the roots of a remnant arc. These rocks form the substrate to a thick succession of silicic volcanic and sedimentary rocks, most of which are of Middle Ordovician age. During the Silurian, the Hermitage Flexure area was affected by a tectono-thermal event, marked by large scale recumbent folding and greenschist to amphibolite facies metamorphism and migmatization. Major synkinematic, multiphase batholiths, containing significant proportions of hornblende-biotite tonalite and granodiorite, were intruded at this time. The granitoids are essentially deformed throughout, and are affected by major D_1 *mylonite zones. Thermal relaxation of thickened crust resulted in the production of post* D_1*, syn* D_2 *muscovite-bearing granites, possibly by progressive partial melting of peraluminous parental material. The area is host to a variety of mineral occurrences, including volcanogenic base metals and uranium, and granite-hosted uranium, molybdenum, tin and tungsten. The potential for epithermal-fumerolic gold mineralization in the volcanic and comagmatic intrusive rocks is high.*

INTRODUCTION

This paper presents a brief overview of the geology of the central portion of the Hermitage Flexure. The major results of the 1:50,000 scale mapping of the Burgeo (11P) map area are summarized (Chorlton, 1980; O'Brien, 1983; Blackwood, 1983, 1984, 1985a; Dickson and Tomlin, 1983; O'Brien and Tomlin, 1984, 1985a, 1985b; Dickson and Delaney, 1984; Dickson *et al.*, 1985; Poole *et al.*, 1985). Related petrochemical studies are in progress and the results of this work will be published at a later date.

The Burgeo map area (Figure 1) is situated on the southwest coast of Newfoundland, bounded by north latitudes 47° 00 and 48° 00' and west longitudes 56° 00 and 58° 00. The physiography of the region is characterized by a peneplain with an average elevation of 330 m, which is disrupted by scattered monadnocks with elevations of 450 to 700 m. The coastal region is dissected by north-south trending fiord-like bays. The area's major rivers - Grandy's Brook, White Bear River, Grey River and Dolland Brook - follow this north-south grain. Elsewhere drainage is controlled by the regional, east-west, structural grain. Much of the Burgeo map area is readily accessible only by aircraft. The town of Burgeo is the largest population centre, with approximately 3000 inhabitants; it is connected to the Trans-Canada Highway by a 160 km all-weather road. From spring to early autumn, Burgeo and the coastal communities of Ramea, Grey River, Francois and McCallum are serviced daily by C.N. Marine and Newfoundland Government ferries.

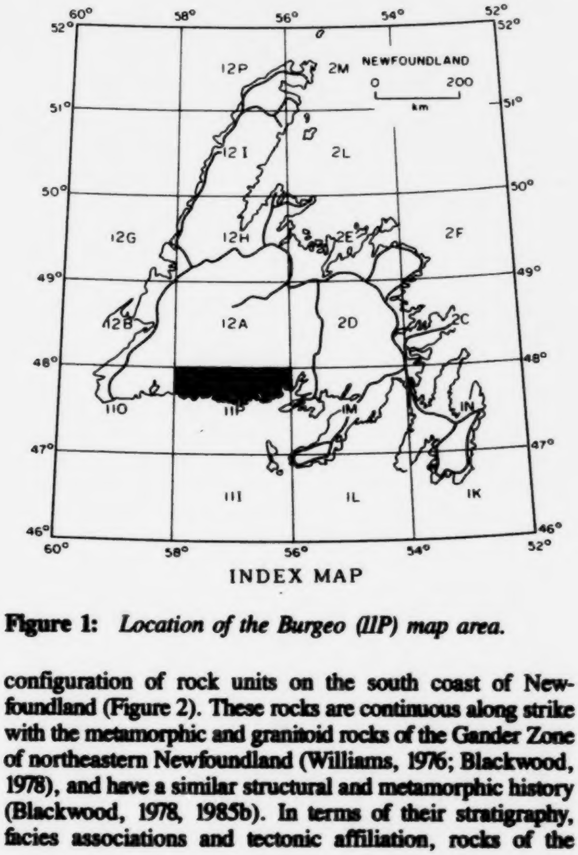

Figure 1: *Location of the Burgeo (11P) map area.*

The Burgeo map area is underlain by early to middle Paleozoic rocks that are structurally dominated by the Hermitage Flexure (Williams *et al.*, 1970), a sinuous Z-shaped configuration of rock units on the south coast of Newfoundland (Figure 2). These rocks are continuous along strike with the metamorphic and granitoid rocks of the Gander Zone of northeastern Newfoundland (Williams, 1976; Blackwood, 1978), and have a similar structural and metamorphic history (Blackwood, 1978, 1985b). In terms of their stratigraphy, facies associations and tectonic affiliation, rocks of the

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This project is a contribution to the Canada-Newfoundland Mineral Development Agreement, 1984-1989

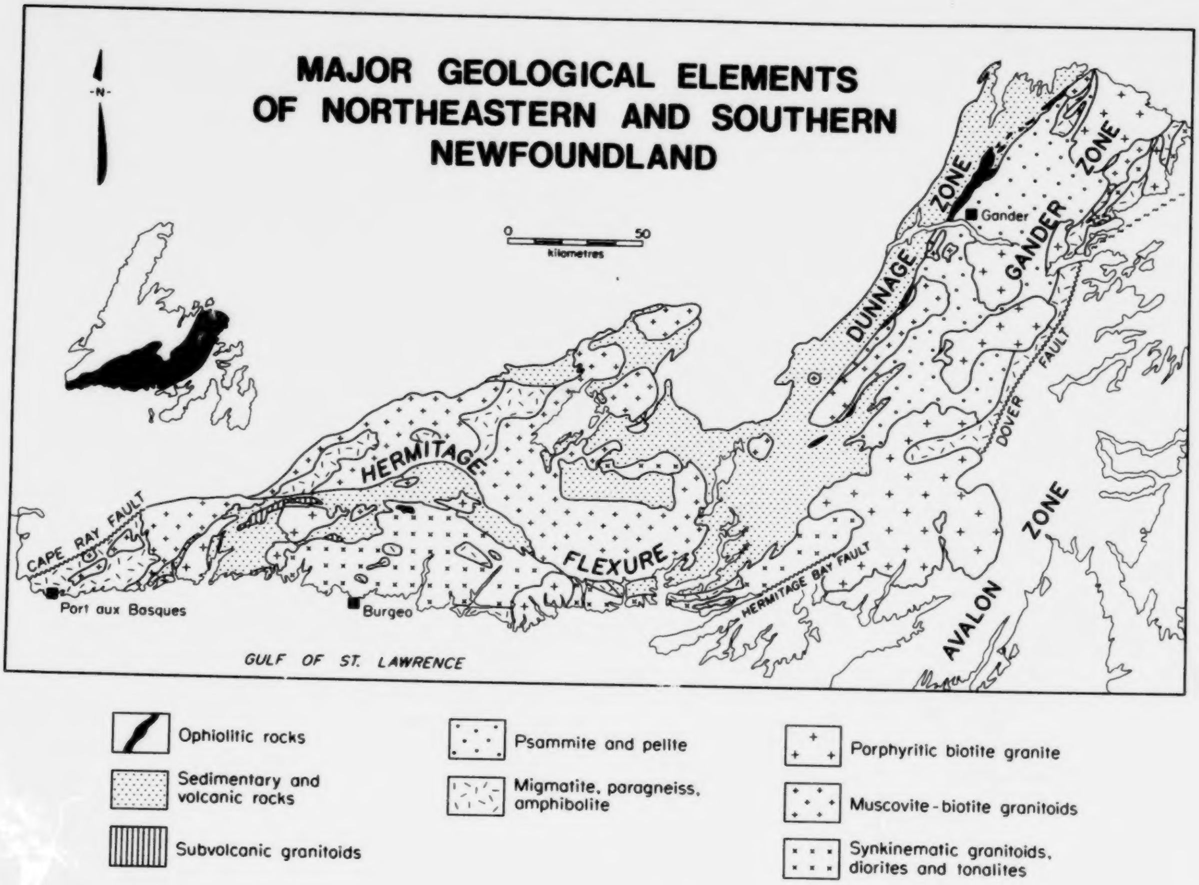
MAJOR GEOLOGICAL ELEMENTS
OF NORTHEASTERN AND SOUTHERN
NEWFOUNDLAND
N
0
50
kilometres
DUNNAGE ZONE
GANDER ZONE
Gander
DOVER FAULT
HERMITAGE FLEXURE
CAPE RAY FAULT
HERMITAGE BAY FAULT
AVALON ZONE
Port aux Basques
Burgeo
GULF OF ST. LAWRENCE
Ophiolitic rocks
Sedimentary and volcanic rocks
Subvolcanic granitoids
Psammite and pelite
Migmatite, paragneiss, amphibolite
Porphyritic biotite granite
Muscovite-biotite granitoids
Synkinematic granitoids, diorites and tonalites

Figure 2: *Major geological elements of northeastern and southern Newfoundland.*

central Hermitage Flexure area are comparable to the Ordovician successions in the Dunnage Zone (e.g., Williams, 1976; Dean, 1978) of central Newfoundland.

The principal stratigraphic components of the region are Lower (?) to Middle Ordovician volcanic and sedimentary rocks of the Bay du Nord and Baie d'Espoir groups. A third unit of regional extent, the volcanic-sedimentary La Poile Group, may include rocks that are either equivalent to, or significantly younger than, the Ordovician rocks. The Bay du Nord and Baie d'Espoir groups are interpreted to have been deposited, at least in part, on an oceanic basement, vestiges of which occur in the western parts of the Burgeo map area. Mafic migmatite-tonalite complexes, which form isolated enclaves within and adjacent to the granitoid plutons, may contain remnants of this basement. The stratified rocks were polydeformed and metamorphosed under middle greenschist to upper amphibolite facies conditions, mainly during the Silurian. The principal phase of deformation produced southward facing, overturned, isoclinal folds. In general, metamorphic grade increases from north to south, culminating in zones of migmatite. The major synkinematic granitoid intrusives, e.g., Burgeo Granite, share the early foliations of the country rocks; locally, the regional foliation intensifies, grading into major D_1 mylonite zones. The second deformation produced upright open folds and associated strain-slip fabrics. In places, the second-phase folds control the regional outcrop pattern of the stratified rocks (e.g., Dolland Brook area; Blackwood, 1984). Syn D_2 granitoids of the North Bay Granite comprise a large, composite batholith that forms the northern margin of the Hermitage Flexure area. Smaller syn D_2 and posttectonic granitoid plutons, e.g., Peter Snout and Cochrane Pond granites, are confined to the metasedimentary and metavolcanic belts. The youngest granitoid rocks are a suite of high level, silica-rich granites (Francois and Chetwynd granites) that intrude the syn D_1 granitoids adjacent to the coast.

The area hosts numerous mineral occurrences, including significant showings of base metals, granitoid-hosted uranium, molybdenum, tin and tungsten mineralization, and uranium in volcanic and sedimentary rocks. The metavolcanic successions of the La Poile, Bay du Nord and Baie d'Espoir groups are important potential hosts for epithermal-fumerolic gold mineralization.

GEOLOGY OF THE BURGEO (11P) MAP AREA

Probable Ophiolitic Rocks

Mafic meta-igneous rocks, interpreted as vestiges of pre-Middle Ordovician ophiolitic crust, are preserved in the western parts of the Burgeo map area (Figure 3). In the Blue Hills of Couteau, Chorlton (1980) described a large, mafic, igneous complex, which occurs as rafts in Ordovician silicic intrusive rocks. It is composed mainly of gabbro cut by diabase and basalt dikes, all intruded by trondhjemite veins. Gabbro massifs, associated with tonalite, occur as xenoliths in the Burgeo Granite (O'Brien, 1983; O'Brien and Tomlin, 1984). The gabbros are correlated with the ophiolitic gabbros of the Blue Hills of Couteau. In the White Bear River area, layered gabbros, cut by diabase and trondhjemite, are associated with pyroxenite and peridotite (O'Brien and Tomlin, 1984) (Plate 1).

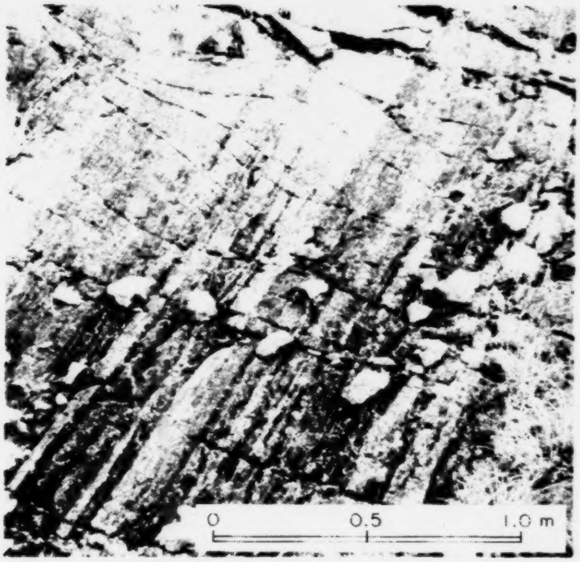

Plate 1: *Layered gabbro injected by diabase, White Bear River (11P/14) map area.*

Similar gabbro bodies shed detritus into the Middle Ordovician Bay du Nord Group, supporting the interpretation that gabbros in the Burgeo map area represent basement rocks. Also, the mafic meta-igneous complexes are thought to be equivalents of the more complete ophiolite successions of the Annieopsquotch ophiolite belt to the north (Dunning and Chorlton, 1985), the Long Range Mafic-Ultramafic Complex of the southern Long Range Mountains to the west (Chorlton and Knight, 1983), and the Coy Pond, Great Bend and Gander River Ultrabasic Belt ophiolites to the northeast (Blackwood, 1982; Colman-Sadd and Swinden, 1982).

Stratified Rocks

Polydeformed, middle greenschist to amphibolite facies metavolcanic and metasedimentary rocks of Ordovician age are the principal stratigraphic components of the central parts of the Hermitage Flexure. The rocks have been named Bay du Nord Group (Cooper, 1954) in the west and Baie d'Espoir Group (Jewell, 1939; Anderson, 1967) in the east. A third group of dominantly subaerial, greenschist facies metavolcanic rocks, the La Poile Group (Cooper, 1954), is faulted against the Bay du Nord Group. The stratigraphic relationship between these two groups is equivocal, although it has been suggested that parts of both may be equivalent (Chorlton, 1978, 1980; O'Brien, 1983). Initial results of U-Pb isotopic studies of zircon indicate that parts of the La Poile Group may be significantly younger than the Bay du Nord Group (G. Dunning, written communication, 1985; unpublished data). The volcanic successions of both groups are intruded by small plugs of comagmatic felsic plutonic rocks.

The *Baie d'Espoir Group* is exposed mainly in a large overturned syncline-anticline pair in the Facheux Bay area (Blackwood, 1983; 1985b). The succession consists of pelitic sedimentary rocks with intercalated felsic volcanic rocks (Isle Galet Formation) that are conformable with psammitic and semipelitic schist (Riches Island Formation). The rocks are progressively metamorphosed southward and are gradational into migmatites (Little Passage Gneiss) in the deeper structural levels. North of the Facheux Bay map area, psammites, pelites and semipelites, correlated with the Salmon River Dam Formation (Colman-Sadd, 1976), are exposed. The Baie d'Espoir Group contains Middle Ordovician fossils (Colman-Sadd, 1976); its isotopic age is unknown.

The *Bay du Nord Group* includes the volcanic and sedimentary rocks in the Burgeo map area that are continuous with rocks in the group's type area near La Poile Bay (Cooper, 1954). The group is bounded in the north by the North Bay Granite and in the south by the Bay d'Est Fault and the Burgeo Granite. The Bay du Nord Group forms an eastward-thinning belt that consists of felsic metavolcanic rocks intercalated with, and overlain by pelitic and psammitic metasedimentary rocks. The volcanic succession is most extensive in the Peter Snout area, where it includes a lower unit of highly strained, felsic, crystal-lithic tuffs. The tuffs contain rare interbeds of psammite and a coarse grained boulder-conglomerate (Plate 2) unit, rich in gabbroic detritus (O'Brien, 1983). The upper part of the volcanic sequence consists of rhyolite, densely welded rhyolitic tuff and felsite; it is overlain locally by a distinctive unit of buff, waterlain tuff associated with minor graphitic pelite (O'Brien, 1983; O'Brien and Tomlin, 1984). The rhyolitic unit is exposed discontinuously as far east as the Dolland Brook area, where it outcrops on both limbs of a large scale F_2 syncline (Blackwood, 1984). In the western part of the Burgeo map area, a rhyolite-bearing pebble conglomerate separates felsic volcanic rocks from overlying graphitic schist, phyllite and semipelite of the Bay du Nord Group (O'Brien, 1983). Elsewhere, a quartz-rich sandstone unit intervenes between volcanic rocks and similar metasedimentary rocks (O'Brien and Tomlin, 1984; Blackwood, 1984). The dominant sedimentary rock types of the Bay du Nord Group are bedded gray sandstone, shale and their metamorphic equivalents (Plate 3). These rocks contain rare interbeds of matrix-supported pebble conglomerate and slump breccia, felsic tuff and tuffaceous sandstone.

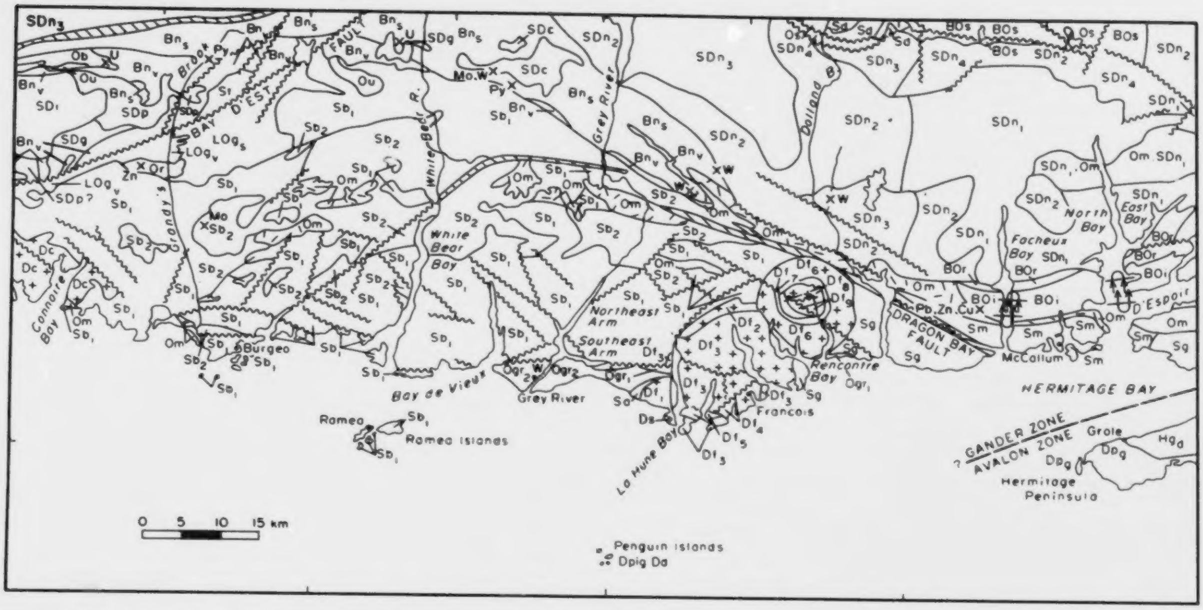
Bay D'Est
Brook
White Bear R.
Grey River
Dolland B.
White Bear Bay
Northeast Arm
Southeast Arm
Bay de Vieux
Grey River
Burgeo
Romeo
Romeo Islands
Connoire Bay
La Hune Bay
Francois
Rencontre Bay
Dragon Bay Fault
McCallum
Hermitage Bay
Gander Zone
Avalon Zone
Grole
Hermitage Peninsula
North Bay
East Bay
Facheux Bay
D'Espoir
Penguin Islands
Dpig Dd
0 5 10 15 km

Figure 3: *Geology of the Burgeo (11P) map area.*

LEGEND

DEVONIAN

Ds	Red and green conglomerate, sandstone, shale and limestone.
Dd	Undivided early and late, massive diabase dikes.
Df	FRANCOIS GRANITE: pink, massive, biotite granite; Df_1, buff, medium grained, feldspar porphyritic granite; Df_2, coarse grained equigranular granite; Df_3, Df_6, coarse grained, K-feldspar porphyritic granite; Df_4, Df_8, buff, medium grained, feldspar porphyritic adamellite and granite; Df_5, pink to white, fine grained, quartz-feldspar-biotite porphyritic granite; Df_7, medium grained, K-feldspar porphyritic granite; Df_9 medium grained equigranular granite.
Dc	CHETWYND GRANITE: medium to coarse grained, equigranular to K-feldspar porphyritic, biotite granite.
Dpg	PASS ISLAND GRANITE: pink, medium to coarse grained, K-feldspar porphyritic, biotite-hornblende granite.
Dpig	PENGUIN ISLANDS GRANITE: pink, medium grained, K-feldspar porphyritic, biotite granite.
Dg	Undivided, medium to fine grained, biotite ± hornblende granite.

SILURIAN - DEVONIAN

SDg	Medium grained muscovite granite and felsite.
SDI	IRONBOUND MONZONITE: massive to locally foliated, medium grained, plagioclase porphyritic, biotite ± hornblende monzonite with minor granodiorite and granite.
SDp	PETER SNOUT GRANITE: massive to weakly foliated, fine to medium grained, equigranular, biotite ± muscovite granite.
SDc	COCHRANE POND GRANITE: massive to weakly foliated, fine to medium grained, muscovite ± biotite granite.
SDn	SDn_1, weakly foliated, medium grained, equigranular to porphyritic, biotite ± muscovite granodiorite, with minor garnet-muscovite granite; SDn_2, massive to weakly foliated, medium to coarse-medium grained, K feldspar porphyritic, biotite granite; SDn_3, massive to weakly foliated, medium to coarse-medium grained, K-feldspar porphyritic, biotite-muscovite granite; SDn_4, strongly deformed to mylonitic, medium to coarse grained, K-feldspar porphyritic, biotite granodiorite, and medium grained equigranular muscovite-garnet granite.

LEGEND *(Continued)*

SILURIAN

Sd	*Dolland Pond Formation:* cleaved pebble conglomerate and breccia, interbedded with shale and sandstone.
Sa	Fine to coarse grained, hornblende gabbro, including hornblendite, diorite and amphibolite.
Sb	BURGEO GRANITE: Sb_1, coarse-medium to coarse grained, massive to foliated, feldspar porphyritic, biotite ± hornblende granodiorite and granite; Sb_2, medium grained, equigranular to porphyritic, biotite ± muscovite ± garnet granodiorite and granite, locally containing abundant migmatite inclusions.
Sm	McCALLUM GRANITE: foliated to mylonitic, medium to coarse grained, equigranular to feldspar porphyritic, biotite granite and granodiorite.
Sg	GAULTOIS GRANITE: mainly coarse grained, strongly foliated to mylonitic, feldspar porphyritic, biotite granodiorite and granite, including minor, medium grained, equigranular granite.
St	TOP POND TONALITE: foliated, medium grained, equigranular, hornblende ± biotite tonalite.

ORDOVICIAN?

Om	Migmatite, agmatite, paragneiss and associated granitoids; locally includes migmatized metasedimentary rocks of known Ordovician age.
Ogr	GREY RIVER ENCLAVE: Ogr_1, felsic tuff and minor metasedimentry rocks; Ogr_2, migmatized pelitic and psammitic schist, mafic schist and amphibolite; minor gabbro, peridotite and granitoid gneiss.
	LA POILE GROUP
LOg	*Georges Brook Formation:* LOg_V, rhyolite flows, ash-flow tuffs, agglomerate, reworked volcaniclastics, minor mafic flows, pyroclastics and dikes; LOg_S, fine to coarse grained, locally cross-stratified sandstone, including quartz-pebble and quartz-cobble conglomerate.
Or	ROTI GRANITE: foliated, equigranular, medium grained, biotite granodiorite and quartz-feldspar porphyry.
Ob	BAGGS HILL GRANITE: massive to weakly foliated, quartz-feldspar porphyritic granite, granodiorite and quartz-feldspar porphyry.

ORDOVICIAN

Os	*Spruce Brook Formation:* strongly foliated psammitic and semipelitic schist and minor schistose felsic volcanic rocks; locally extensive, cleaved, quartz-pebble conglomerate and quartzite.
	BAY DU NORD GROUP
Bn	Bn_V, felsic pyroclastic rocks, rhyolite, and welded tuff associated with mafic volcanic rocks and clastic sedimentary rocks; Bn_S, psammite, semipelite and pelite, including quartz-rich sandstone and quartz-pebble conglomerate.
	BAIE D'ESPOIR GROUP
BOr	*Riches Island Formation:* semipelitic schist, including thin to thick bedded psammitic schist and minor quartzite.
BOI	*Isle Galet Formation:* felsic volcanic rocks and overlying graphitic pelite, arenite and minor tuff, conglomerate, limestone and ampbibolite.
BOs	*Salmon River Dam Formation:* psammite and pelite containing minor calcareous psammite and limestone.

ORDOVICIAN OR EARLIER

Ou	Layered metagabbro and metadiabase; minor pyroxenite and peridotite; rare mafic volcanic rocks.

HADRYNIAN

Hgd	GROLE DIORITE: medium to coarse grained, hornblende-pyroxene gabbro and hornblende-biotite diorite, and quartz diorite.

Plate 2: *Flattened, boulder conglomerate containing gabbroic detritus, Bay du Nord Group.*

Plate 4: *Coarse, pumice-bearing, ash-flow tuff, La Poile Group.*

Plate 3: *Interbedded shale, sandstone and quartzose granule conglomerate, Bay du Nord Group.*

Plate 5: *Epiclastic volcanic breccia (lahar), La Poile Group.*

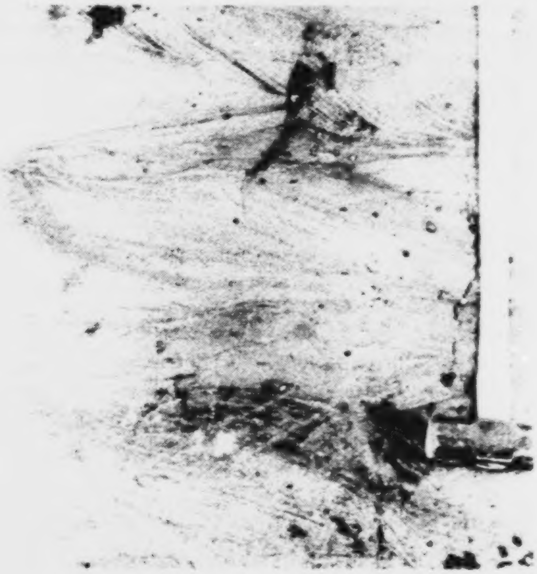

Plate 6: *Cross-bedded sandstone, La Poile Group.*

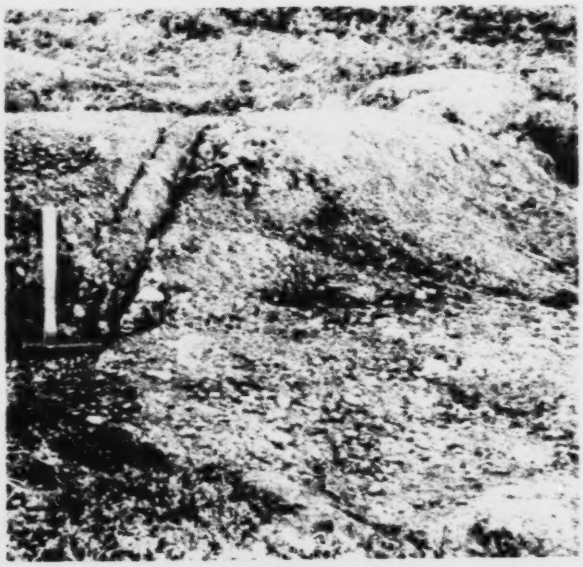

Plate 7: *Quartz-pebble conglomerate, La Poile Group.*

No fossils have been found in the Bay du Nord Group. However, a recent U-Pb age determination from felsic volcanic rocks in the Dolland Brook area of 468 ± 2 Ma (T. Krogh, written communication, 1985) is taken as evidence of a Middle Ordovician age, and supports the correlation of the Bay du Nord and Baie d'Espoir Groups.

The *La Poile Group*, as defined in La Poile Bay in the Port aux Basques (110) map area (Chorlton, 1978), consists of a structurally lower succession of metabasic dikes, tuffs and flows that is intruded by a polyphase tonalitic to granodioritic intrusion, an intervening unit of sandstone and boulder conglomerate, and an upper succession of rhyolite flows and ash-flow tuffs (Chorlton, 1978; Swinden, 1981). In the Burgeo map area, the La Poile Group consists of felsic pyroclastic and associated epiclastic rocks, interdigitated with, and overlain by fluvial, cross-bedded, quartzose sandstone and quartz-pebble conglomerate (O'Brien, 1983).

The main volcanic rock types are ash-flow tuffs, lahars and related, finer grained, epiclastic rocks (Plates 4 and 5). The ash flows are variably welded and quartz-phyric, and are of rhyolitic and rhyodacitic composition. They are associated with an eastward-fining sequence of laharic breccias, presumably related to volcanic activity to the west, where the ash-flow tuffs predominate (e.g. Chorlton, 1979). The welded ash flows are not extensively developed to the east of Grandy's Brook, where the volcanic rocks are mainly of airfall and epiclastic origin (O'Brien, 1983).

The lower half of the La Poile Group clastic succession consists of medium and coarse grained, immature quartz arenite, feldspathic lithic arenite, pebbly sandstone and granule conglomerate, all of which are rich in blue quartz (O'Brien, 1983). The sandstones are massive to thickly bedded, internally cross-bedded (Plate 6) and very rarely planar-bedded. Interlayered with the sandstones are 1 to 5 m thick beds of angular, poorly sorted, locally cross-bedded, granule and cobble to boulder conglomerate (Plate 7). Conspicuous angular clasts of vein quartz, up to 15 cm in diameter, occur in a quartz-rich sandy matrix; the detrital assemblage of the conglomerate includes up to 90 percent vein quartz.

The remainder of the La Poile Group clastic succession is mainly gray, fine to medium grained, cross-bedded, feldspathic sandstone. It is finer grained, less quartz-rich and more mature than the lower parts of the group, and does not contain the thick conglomerate lenses and beds that are common elsewhere.

The stratigraphic relationship of the La Poile and Bay du Nord groups is problematic. Cooper (1954) suggested that the La Poile Group unconformably overlies the Bay du Nord Group, whereas Chorlton (1978, 1980) proposed that the La Poile and Bay du Nord groups were time-stratigraphic equivalents. The general similarity in composition and facies of the volcanic rocks of the La Poile and Bay du Nord groups, coupled with the U/Pb and Rb/Sr isotopic data reported in Chorlton (1980) and Loveridge and Chorlton (1985), support the interpretation that both groups are time-stratigraphic equivalents. However, recent precise U-Pb geochronology (G. Dunning, written communication, 1985), together with contrasts between the groups in sedimentary facies (O'Brien, 1983) and metallogeny (Swinden, 1981) could be taken as evidence against such a correlation. Data resulting from ongoing and proposed geochronological and petrochemical studies, together with detailed mapping in the groups' type areas (east of La Poile Bay), are expected to resolve this problem.

It is important to note that Chorlton's (1978) definition of the La Poile Group differs from that of Cooper (1954) in that the former includes the metabasic rocks and associated granitoids structurally beneath the conglomerate unit, which Cooper (1954) had excluded from the group. The nature of the metabasic unit and its relationship to adjacent units and the felsic volcanic succession are outstanding problems that need to be addressed.

Near Grey River, a conformable sequence consisting of felsic metavolcanic rocks, pelitic to psammitic metasedimentary rocks and migmatites forms an isolated west-trending belt named the Grey River enclave (Blackwood, 1985a). These rocks are faulted against the Burgeo Granite (Blackwood, 1985a). Because of similarities in lithology and structural style, these rocks have been tentatively correlated with the Ordovician rocks that occur elsewhere around the Hermitage Flexure (Blackwood, 1985a).

Rocks of the Ordovician Spruce Brook Formation are found in the northern margin of the area, near Dolland Brook. Exposures include clast-supported pebble to boulder conglomerate, rich in orthoquartzite clasts (Dickson, *in preparation)*. These rocks are in fault contact with the Salmon River Dam Formation of the Baie d'Espoir Group.

At Dolland Pond, sedimentary rocks of possible Silurian age are exposed. The succession consists of gray to black shale and siltstone, interbedded with, and overlain by pebbly sandstone, polymictic pebble conglomerate and sedimentary breccia. The conglomerate contains clasts of vein quartz, rhyolite, basalt, chert and clastic sedimentary rocks typical of the North Steady Pond Formation of the Baie d'Espoir Group (Colman-Sadd, 1984).

A small area of gently dipping, upward facing, pale-green, gray, and reddish brown granule to pebble conglomerate occurs at the entrance to La Hune Bay. The conglomerate is interbedded with sandstone and siltstone which grade into white weathering carbonate-rich layers. The contact between the sedimentary rocks and the Francois granite was originally interpreted as intrusive (Williams, 1971), but it appears to be a nonconformity (Blackwood, 1985a). These rocks are posttectonic with respect to the deformation in the Grey River enclave and may be Devonian or later in age (Williams, 1971).

Migmatites and Associated Rocks

Migmatite, together with metasedimentary and granitoid rocks, is spatially associated with the Bay du Nord Group and syn D_1 intrusive rocks in a discontinuous band that extends from Long Island, Bay d'Espoir, westward to Grandy's Brook. The migmatites commonly occur as enclaves of variable size, mainly within the equigranular granitoid phases of the Burgeo Granite. Individual zones may be as large as 50 km²; their areal distribution reflects the general structural trend of the Hermitage Flexure. In general, migmatites in the southern portion of the region have a mafic meta-igneous component, whereas those in the north and east are mainly higher-grade metamorphic equivalents of the metavolcanic and metasedimentary stratified succession.

In the Facheux Bay map area, migmatite, amphibolite and recrystallized metasedimentary rocks (Little Passage Gneiss) represent the deepest structural levels of the Bay d'Espoir Group; these rocks are exposed on the overturned limb of a major F_1 anticline (Blackwood, 1985b). The high-grade rocks are gradational, structurally upward, into less metamorphosed psammite and semipelite (Isle Galet Formation). In the White Bear River map area (O'Brien and Tomlin, 1984), migmatite, amphibolite and recrystallized pelitic, semipelitic and psammitic schists, together with refolded, cataclastically deformed granite, occur in large rafts within equigranular granite phases of the Burgeo Granite. The protoliths of the metamorphic rocks are assumed to be parts of the Ordovician stratified successions, and perhaps even the earliest phases of the synkinematic granitoids. In the Peter Snout map area, migmatized quartz-pebble conglomerates are gradational, through a zone of granitoid injection, into recrystallized metasedimentary rocks that pass into greenschist grade quartzose conglomerate and sandstone of the La Poile Group (O'Brien, 1983).

Migmatite and associated metamorphic rocks are a major component of the Grey River enclave (Blackwood, 1985a). At Grey River, metavolcanic, metasedimentary and pretectonic mafic and ultramafic rocks exhibit a southward increase in metamorphism and degree of migmatization within the enclave. The metasedimentary migmatites have concordant contacts with a major amphibolite unit, which is gradational into mafic migmatite. Granodioritic gneiss, rich in mafic inclusions, occurs south and west of the mafic migmatite. It is interpreted to be the result of progressive deformation of an agmatite that was produced by granitoid-intruded amphibolite (Blackwood, 1985a).

Similar mafic migmatite (Plate 8), associated with plagiogranite, is exposed as inclusions in the Chetwynd Granite. These metamorphic rocks form the eastward extension of Chorlton's (1980) Cinq Cerf Complex, an Ordovician(?) metamorphic complex of mainly mafic composition, which is here considered to be correlative with parts of the Grey River enclave.

Agmatite and mafic migmatite form a 2 km wide belt adjacent to the Burgeo Granite along the coast near Burgeo (O'Brien and Tomlin, 1985a). The agmatites are gradational into the migmatitic rocks and consist of massive to banded gabbro and diorite xenoliths in a granodioritic host. The proportion of matrix varies greatly within the agmatitic rocks, and mafic inclusions show varying degrees of assimilation. Banding in the migmatites is variable; the migmatites are characteristically nebulitic or schlieric, and are rarely well layered. The protolith of the mafic component of the migmatite, and of the mafic blocks in the agmatite, is layered gabbro of uncertain origin; the gabbro may represent either early mafic phases of the Burgeo Granite or Ordovician

Plate 8: *Mafic migmatite; large inclusion within the Chetwynd Granite.*

ophiolitic rocks. O'Brien and Tomlin (1984) have suggested that the agmatite-migmatite zone was genetically related to early plutonic activity associated with intrusion of the Burgeo Granite.

Within the Dolland Brook and D'Espoir Brook map areas, migmatitic metasedimentary rocks occur mainly as xenoliths of extremely variable size within the North Bay Granite (Dickson and Tomlin, 1983; Dickson and Delaney, 1984). The origin of the migmatites is uncertain. They appear to be the result of high-grade metamorphism and *in situ* melting of country rocks. However, some may be the product of granitoid injection of metasedimentary rocks at the margin of the North Bay Granite.

The main area of migmatite occurs immediately to the east and west of North Bay and is commonly cut by dikes of North Bay Granite and pegmatite veins. The neosome of muscovite-biotite granodiorite, which comprises up to 50 percent of the migmatite, is equigranular and exhibits a variably developed foliation. The paleosome is dominantly a sillimanite-bearing, quartz-plagioclase-biotite psammite. Commonly, biotite-muscovite (± sillimanite) semipelitic schist forms isolated xenoliths within the migmatite.

The migmatites are considered to be derived from the Riches Island and Salmon River Dam formations, as there is a pronounced increase in the abundance of xenoliths within the North Bay Granite along its southern and northern contacts with the Ordovician country rocks. Along the southern contact, in particular, there is an essentially transitional zone, 2 to 4 km wide, between the granite and the metasedimentary rocks. The belt of migmatite in the central North Bay area may represent a roof pendant in the North Bay Granite.

Migmatite is locally abundant in the area south and southeast of Dolland Pond where it is mainly associated with the elongate belt of deformed granitoids. The protolith of these migmatites is enigmatic. The nearest exposed source of migmatite is the Ordovician Spruce Brook Formation to the north of the Dolland Brook (11P/15) map area. Xenoliths of non-migmatitic psammitic schist are similar to the psammites which form part of the Spruce Brook Formation (Colman-Sadd and Swinden, 1982).

Plutonic Rocks

Plutonic rocks underlie a major part of the central Hermitage Flexure area. On the basis of radiometric data and regional structural considerations, the granitoids in the Burgeo map area can be divided into four main groups. These include: pretectonic, syntectonic, late-syntectonic, and posttectonic granitoids.

Pretectonic Granitoids

Roti Granite. Chorlton (1980) correlated a small area of granodiorite and quartz-feldspar porphyry, west of Grandy's Brook, with the Roti Granite near Grand Bruit, in the La Poile (11O/9) map area (Cooper, 1954; Chorlton, 1979). In the latter locality, Chorlton (1979) described dikes of Roti Granite intrusive into La Poile Group rocks, which contained clasts of the same granite. On the basis of this relationship, Chorlton (1979, 1980) suggested that the La Poile Group and the Roti Granite were comagmatic. Recent examination of the Roti Granite west of Grandy's Brook (J. Tuach, personal communication, 1985) suggests that a significant part of the Roti Granite is actually highly altered felsic volcanic rocks. The main rock type of the Roti Granite is medium to coarse grained, plagioclase porphyritic, biotite granodiorite.

In the Peter Snout map area, intrusive contacts between the Roti Granite and the La Poile Group have not been documented. O'Brien (1983) described foliated clasts of Roti Granite within the upper, clastic portion of the La Poile Group. Similar evidence presented by Chorlton (1980) indicates that the upper part of the La Poile group is younger than the Roti Granite. Evidence for an intrusive contact is based on an assumption that the Roti Granite at Grand Bruit is equivalent to the granite west of Grandy's Brook.

Baggs Hill Granite. The eastern extension of the Baggs Hill Granite (Cooper, 1954) is exposed in the northwest corner of the Burgeo map area, where it intrudes the Bay du Nord Group (Chorlton, 1980). Quartz-plagioclase porphyry forms its most extensive phase, associated with equigranular, biotite granodiorite. Chorlton (1980) has interpreted the granite to be a synvolcanic intrusion, genetically related to volcanic rocks of the Bay du Nord Group.

Syntectonic granitoids

Gaultois Granite. The dominant rock type of the Gaultois Granite within the Burgeo map area is strongly foliated to mylonitic, coarse grained, feldspar porphyritic, locally hornblende-bearing, biotite granodiorite. The pluton is mylonitic along the Dragon Bay Fault and along its contact with strongly sheared felsic volcanic rocks in the Devil Bay-

Hare Bay area. Correlatives of this granite have been isotopically dated (Rb-Sr whole rock) at approximately 448 Ma (R. Cormier, written communication to S.P. Colman-Sadd, 1973). An Rb-Sr age of 350 ± 18 Ma from the Gaultois area (Elias, 1981; Elias and Strong, 1982) conflicts with an Rb-Sr age (Bell *et al.*, 1977) and an $^{40}Ar/^{39}Ar$ age (Dallmeyer *et al.*, 1983), both 350 ± 10 Ma, on the Ackley Granite, which intrudes the Gaultois Granite.

Plate 9: *Banding in granite defined by variations in grain size and the amount of biotite, McCallum Granite.*

McCallum Granite. The McCallum Granite consists predominantly of variably banded granitoid which locally grades into zones of homogeneous porphyritic granite. The banded variety (Plate 9) is generally grayish white weathering, medium to coarse grained, variably porphyritic, biotite granite-grandiorite. For the most part, the banding (interpreted as primary) is defined by variations in grain size, the amount of biotite, and the number of feldspar phenocrysts. Bands are 1 cm to 1 m wide and locally persist in three dimensions with straight, approximately parallel, boundaries; contacts are abrupt but not intrusive. Individual bands consists of equigranular, minor biotite granite, biotite-rich granite, coarse grained, feldspar porphyritic granite, fine to medium grained granodiorite and, rarely, dark gray diorite. Some textural and compositional variations are lensoid and pinch out along strike. Locally elliptical inclusions of granodiorite occur in granite and vice versa.

The contact of the McCallum Granite with the Baie d'Espoir Group is marked by a several metre wide zone of partially assimilated xenoliths of metasedimentary rocks in the granite. The granite is finer grained near the contact; veins of equigranular biotite granite locally intrude the metasedimentary rocks north of the contact. A moderate to strong foliation, parallel to the trend of layering, is developed throughout the McCallum Granite. West of Facheux Bay, the regional D_1 foliation in the McCallum Granite culminates in a northwest trending mylonite zone known as the Dragon Bay Fault (Blackwood, 1983). The mylonite zone is approximately 1 km wide and separates the McCallum and Gaultois granites west of Facheux Bay; both granite protoliths are recognizable on either side of a 100 to 200 m wide central zone of ultramylonite. Every gradation from protomylonite to ultramylonite occurs within the fault zone.

The highest grade rocks of the Baie d'Espoir Group are spatially related to the McCallum Granite. This observation, together with the fact that the banding in the granite mostly parallels the regional foliation in the country rocks, is considered evidence for the synkinematic nature of the granite. Garnet-muscovite dikes post-date the initial onset of deformation since, locally, xenoliths of McCallum Granite contain an internal foliation that has been rotated slightly in leucogranite dikes, which contain the same strong regional foliation as the rest of McCallum Granite.

Burgeo Granite. The Burgeo Granite is an extensive, composite, granitoid intrusion with compositions ranging from hornblende gabbro, quartz diorite and biotite tonalite to muscovite-biotite granite and biotite alaskite. Most units contain at least one variably developed regional foliation, although a tectonic fabric is not everywhere obvious. Ongoing geochemical studies indicate that the Burgeo Granite (on Figure 3) includes several individual plutons, some of which may be of significantly different ages, and petrogenetically unrelated.

The dominant rock types of the Burgeo Granite are medium-coarse to coarse grained, K-feldspar porphyritic, locally hornblende-bearing, biotite granodiorite, and coarse grained, K-feldspar porphyritic, biotite granite (Plate 10).

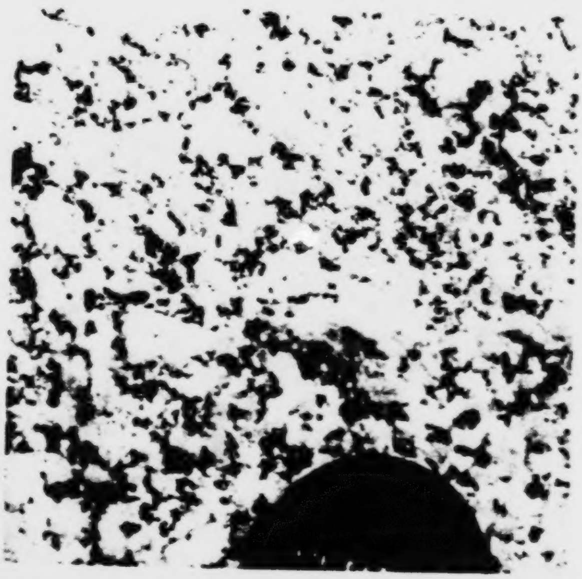

Plate 10: *Coarse grained, K-feldspar porphyritic, biotite granite, Burgeo Granite.*

These intrude the more mafic granitoids and gabbroids, and are intruded by the medium grained, equigranular to K-feldspar porphyritic, locally muscovite-bearing, biotite granodiorite and granite (Plate 11). Thus, a general intrusion sequence from mafic to leucocratic granitoids is apparent, although there may be no genetic link between the earlier granodiorites and the younger muscovite-bearing phases.

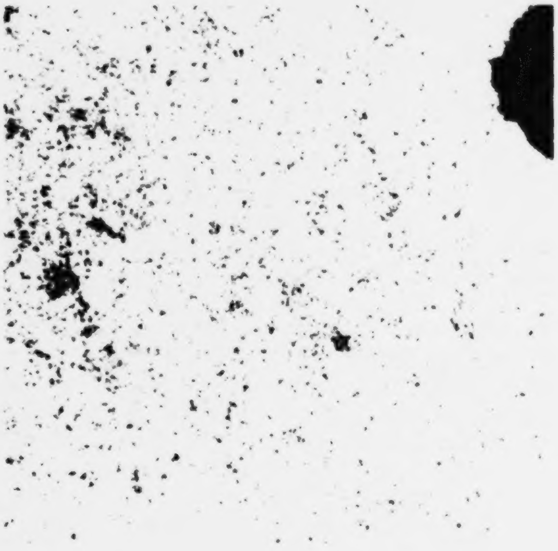

Plate 11: *Equigranular granite phase of the Burgeo Granite.*

The Burgeo Granite intrudes the Ordovician metasedimentary and metavolcanic rocks of the Bay du Nord Group, and sedimentary and volcanic rocks of the La Poile Group. The granite contains the regional D_1 foliation but locally granite dikes crosscut the D_1 structures, indicating the syntectonic intrusive history of the Burgeo Granite. A major D_1 mylonite zone occurs within the granite near its contact with the Bay du Nord Group in the Hare Bay-Dolland Brook area (Blackwood, 1983; Dickson and Delaney, 1984; Dickson *et al.*, 1984). The mylonite zone curves southwestward within the Burgeo Granite west of the Dolland Brook map area (O'Brien and Tomlin, 1984), where it merges with a late brittle fault southwest of White Bear Bay (Dickson *et al.*, 1985). The southern contact between the Burgeo Granite and probable Ordovician sedimentary and volcanic rocks of the Grey River enclave is also a mylonite zone. (Blackwood, 1985a; Dickson *et al.*, 1985).

T. Krogh (written communication, 1985) has reported a probable age of 428.5 ± 4 Ma on zircons from coarse grained, foliated, K-feldspar porphyritic, biotite granite. Similarly, an approximate age of 421 Ma was obtained from weakly foliated, medium grained, equigranular, biotite granite, which intrudes the coarse grained, porphyritic biotite granite. Although these ages appear to bracket the main intrusive activity, field evidence indicates that still younger and older phases, undivided on Figure 3, exist within the Burgeo Granite.

Top Pond Tonalite. The Top Pond tonalite is a black and white, medium grained, equigranular, hornblende-biotite tonalite that occurs within and to the north of the Bay d'Est Fault in the Peter Snout map area (O'Brien, 1983). The tonalite is interpreted to intrude the Bay du Nord Group, although no evidence of an intrusive contact is exposed. It is foliated in most areas and mylonitized along the Bay d'Est Fault. Locally, the tonalite contains xenoliths of gabbro and diorite. This intrusion may be genetically related to rocks of similar composition in the Burgeo Granite, and in the tonalite-ophiolite terrane to the north (e.g., Dunning and Chorlton, 1985).

Late-syntectonic granitoids

North Bay Granite. The North Bay Granite (Jewell, 1939) is an extensive, composite batholith underlying an area of approximately 3000 km². Dominant rock types include medium-coarse to coarse grained, K-feldspar porphyritic, locally muscovite-bearing, biotite granite, and medium grained, equigranular to feldspar porphyritic, muscovite and/or biotite granodiorite and granite. Locally,extensive areas of garnetiferous, muscovite granite and pegmatite are associated with the granodiorite.

The granodiorite phase of the North Bay Granite is dominant in the Facheux Bay (11P/9) and D'Espoir Brook (11P/16) map areas. The granite phase dominates in the Dolland Brook (11P/15) map area and continues to the north into the Burnt Pond (12A/3) and Wolf Mountain (12A/2) map areas. Smaller plutons of K-feldspar porphyritic, coarse grained, biotite granite intrude the granodiorite phase. This suggests that the coarse grained granite,in general, is younger than the medium grained granodiorite.

The northern contact with the Baie d'Espoir Group is either intrusive or faulted. Cataclastic to mylonitic granitoids occur along the northern contact and these are less deformed away from the contact, for a distance of 1 km. The southern and eastern contact with the Baie d'Espoir Group is an intrusion zone of granite and metasedimentary screens; the latter are more abundant toward the contact with country rocks. An extensive thermal aureole is developed, defined by prominent staurolite, garnet and biotite porphyroblasts that overprint the S_1 and S_2 foliations in the Baie d'Espoir Group (Plate 12); locally, porphyroblasts form augen in S_2 fabric planes. Granitoid dikes from the North Bay Granite are deformed by subsequent D_2 structures. These relationships demonstrate the syn D_2 nature of the North Bay Granite.

Xenoliths of migmatite are common within the granodiorite phase of the North Bay Granite. The migmatite is interpreted to be a high-grade metamorphic equivalent of the Ordovician metasedimentary rocks of the Baie d'Espoir Group.

The coarse grained granites of the North Bay Granite are much less deformed than the granodiorites. Xenoliths of migmatite are also far less abundant than in the granodiorite, and are generally found only near the contacts with the Bay du Nord and Baie d'Espoir groups. An S-type affinity has been indicated for the equivalent rocks in the Granite Lake area (Dickson, 1982).

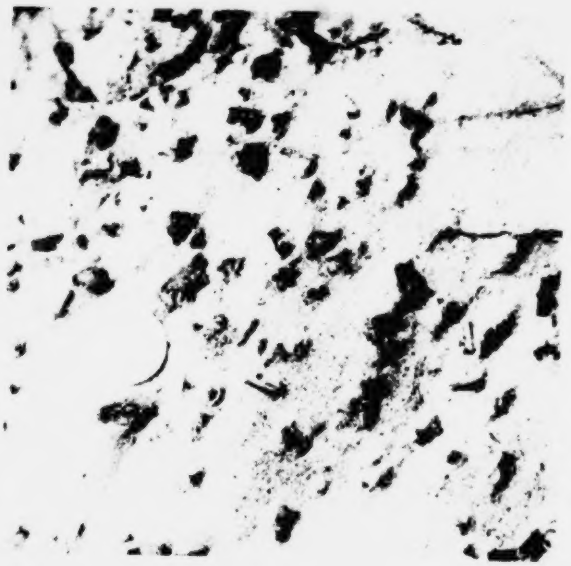

Plate 12: *Staurolite porphyroblasts in semipelite within metamorphic aureole of the North Bay Granite.*

U-Pb zircon dates have been obtained from the North Bay Granite (T. Krogh, written communication, 1985; Dickson *et al.*, 1985). The samples were obtained from massive, coarse grained, K-feldspar porphyritic, biotite granite at Dolland Brook. Two zircon fractions have identical $^{206}Pb/^{238}U$:$^{207}Pb/^{235}U$ ages of 396 Ma and this age is interpreted to be the age of crystallization of the granite phase of the North Bay Granite. A 390 ± 2 Ma date for cooling below 600°C was obtained from monazites extracted from the samples that gave the zircon date.

Penguin Islands granite. The Penguin Islands are underlain by weakly foliated, pink K-feldspar porphyritic granite, which is intruded by two suites of diabase dikes. The earlier dikes have chilled irregular margins. They are veined by the granite and, in places, form inclusions within the granite; dike emplacement clearly resulted in granite remobilization. Later, massive, fine grained dikes intrude both the granite and the earlier dikes. The Penguin Islands granite (informal name) is lithologically similar to the Pass Island Granite on the Hermitage Peninsula.

Cochrane Pond Granite. The Cochrane Pond Granite (O'Brien and Tomlin, 1984) intrudes metasedimentary rocks of the Bay du Nord Group. Its characteristic rock type is quartz-rich, leucocratic, fine to medium grained, equigranular, muscovite-biotite granite. The granite is either undeformed or weakly foliated, and locally it is sericitized and saussuritized. The granite is intruded locally by tourmaline-bearing, quartz-rich, pegmatite dikes. Associated with the leucogranite are aplite dikes containing lepidolite, tourmaline and garnet. Locally, the equigranular phase is associated with slightly porphyritic granite.

Ironbound monzonite. The Ironbound monzonite (informal name) is an extensive, late syntectonic to posttectonic, composite pluton, which intrudes the Bay du Nord Group. $^{40}Ar/^{39}Ar$ dates of 350 Ma from biotite and 361 Ma from hornblende have been reported from the monzonite (Chorlton and Dallmeyer, 1986). The Ironbound monzonite is composed mainly of medium grained, plagioclase porphyritic, monzonite and quartz monzonite; gray, medium grained, locally hornblende-bearing, biotite granodiorite is the subordinate phase. The monzonite phases are unusually rich in apatite, and contain biotite, hornblende and augite. The relationship between the monzonite and granodiorite is not known; Chorlton's (1980) observation that the monzonite is massive and the granodiorite is variably foliated possibly indicates that the monzonite is younger and posttectonic. A feature of the entire Ironbound monzonite is its anomalously high gamma radiation.

Peter Snout Granite. The Peter Snout Granite (O'Brien, 1983) is an unfoliated, medium grained, equigranular, leucocratic, locally garnet- and tourmaline-bearing, biotite-muscovite granite. Chorlton (1980) described foliated, garnet- and muscovite-bearing phases associated with the massive granite. The Peter Snout Granite is intrusive into undivided, syntectonic tonalite and granite in the south (Chorlton, 1980); its contact is gradational and is marked by a wide zone of dikes. The granite contains numerous inclusions of Bay du Nord Group metasedimentary and metavolcanic rocks.

Posttectonic granitoids

Chetwynd Granite. The Chetwynd Granite (Cooper, 1954) is a posttectonic pluton composed of equigranular to K-feldspar porphyritic, medium to coarse grained, biotite granite. The granite is characteristically pink to red, quartz-rich and leucocratic.

Tuffisite veins, which occur near the eastern contact, and miarolitic cavities indicate the high-level nature of the Chetwynd Granite. Numerous related dikes of rhyolite and microgranophyric quartz-sanidine porphyry intrude the Burgeo Granite and occur up to 15 km from the Chetwynd Granite contact (O'Brien and Tomlin, 1984). Inclusions of the older granites, migmatites and amphibolites are common around the margins of the Chetwynd Granite, with some zones up to 1 km in width.

The Chetwynd Granite intrudes the Burgeo Granite and the Bay du Nord Group, and has yielded zircons dated at 377 ± 20 Ma (Dallmeyer, 1980). $^{40}Ar/^{39}Ar$ spectra for biotite from the granite in the Burgeo area indicate a cooling age of 372 ± 5 Ma for the Chetwynd Granite (Dallmeyer, 1980).

Francois Granite. The Francois Granite is a complex, composite, quartz-rich granite, which is lithologically and, in part, chemically similar to the Chetwynd Granite. The Francois Granite is composed of six major rock types, which form ten mappable units in two, overlapping, variably developed, ring complexes (see Dickson *et al.*, 1984; Poole *et al.*, 1985). The rock types include 1) leucocratic and mesocratic, coarse grained, K-feldspar porphyritic, biotite ± muscovite granite, 2) medium and coarse grained equigranular, biotite granite, and 3) fine grained, quartz-feldspar-biotite porphyritic granite. Dikes that intrude the country rocks vary from fine grained, equigranular, biotite granite to very fine grained, quartz-sanidine-biotite rhyolite porphyry. These dikes occur up to 8 km from the northern contact of the Francois Granite.

The Francois Granite is intrusive posttectonically into the synkinematic Burgeo and Gaultois granites and the late syntectonic North Bay Granite. Major shear zones, such as the Dragon Bay Fault, are intruded by undeformed dikes of Francois Granite.The only tectonism to have affected the Francois Granite is reflected in the numerous west- and northwest-trending fractures and minor faults.

The presence of 1) miarolitic cavities, 2) extensive, fine grained, granophyric, quartz-feldspar porphyritic margins to units, 3) probable greisens, and 4) a narrow metamorphic aureole indicates that the pluton was intruded at a high structural level. The well developed ring complex suggests that the Francois Granite was probably emplaced by cauldron subsidence.

STRUCTURAL AND METAMORPHIC HISTORY

The structure of the Baie d'Espoir Group is dominated by upright to recumbent F_1 folds in the Burgeo map area (Blackwood, 1983, 1985). The regional penetrative D_1 foliation is axial planar to these larger scale folds; dips mimic the attitude of their axial surfaces. The S_1 foliation is most intense on the overturned limb of the large scale Manual Arm Anticline (Blackwood, 1985), in the Facheux Bay map area. Fold geometry and regional stratigraphy indicate that the highest grade rocks (Little Passage Gneiss) are exposed on the lower limb of the anticline, and are the metamorphic equivalents of higher structural levels of the Baie d'Espoir Group. The Little Passage Gneiss is intruded by foliated biotite granite of the McCallum and Gaultois granites; both intrusions display a penetrative, locally cataclastic, foliation which corresponds to S_1 in the Baie D'Espoir Group. In the Facheux Bay area, S_1 culminates in a major zone of protomylonite marking the Dragon Bay Fault (Blackwood, 1983). Early structures are refolded by upright F_2 folds; a strain-slip cleavage of varying intensity is superimposed upon the S_1 schistosity. Locally, the second fabric is composite, having completely transposed S_1.

The main regional metamorphism, which accompanied the first deformation of the Baie d'Espoir Group, occurred under middle to upper greenschist facies conditions. In highest structural levels, oriented sericite and biotite, with rare garnet augen, define the first schistosity. Metamorphic grade increases structurally downward, culminating in amphibolite facies rocks that have a foliation defined by coarse grained muscovite and biotite, and quartz and granitoid segregations. At still deeper structural levels, increased recrystallization, partial melting and *lit-par-lit* injection characterize migmatites of the Little Passage Gneiss (Blackwood, 1985).

A second deformation cleavage is superimposed on S_1 throughout much of the Baie d'Espoir Group, and is locally axial planar to upright F_2 folds. The axial trace of these structures is generally subparallel or parallel to F_1 structures. Where superimposed on overturned F_1 structures, the F_2 folds face downward. The Baie d'Espoir Group is overprinted by a hornblende-hornfels facies metamorphic assemblage (Blackwood, 1983; Dickson and Tomlin, 1983) within the aureole of the North Bay Granite. The S_2 crenulation cleavage locally contains augen of granite-related porphyroblasts (Blackwood, 1985b).

The Bay du Nord Group was polydeformed and metamorphosed by the same regional tectonic events that affected the Baie d'Espoir Group. The regional, closely spaced, penetrative D_1 foliation is pervasive throughout the Bay du Nord Group. Many of the pyroclastic rocks are highly strained and lineated, and although the more massive flows rarely display macroscopic flattening, the porphyritic varieties contain flattened feldspars with well developed tails. Metasedimentary units typically display a fine penetrative foliation that is generally coplanar to bedding and, in places, axial planar to small scale isoclinal F_1 folds. The early phases of the Burgeo Granite share the regional D_1 foliation of the Bay du Nord Group; veins of the granite also define F_1 folds that are locally overprinted by the S_2 cleavage. Within the granitoids, fabric intensity is variable; this is due in part to the synkinematic nature and variable age of certain phases of the Burgeo Granite. Locally, the regional foliation intensifies and culminates in zones of protomylonite and ultramylonite (Plate 13). In places, these zones terminate within the granitoids they deform, further indicating the synkinematic nature of these granites.

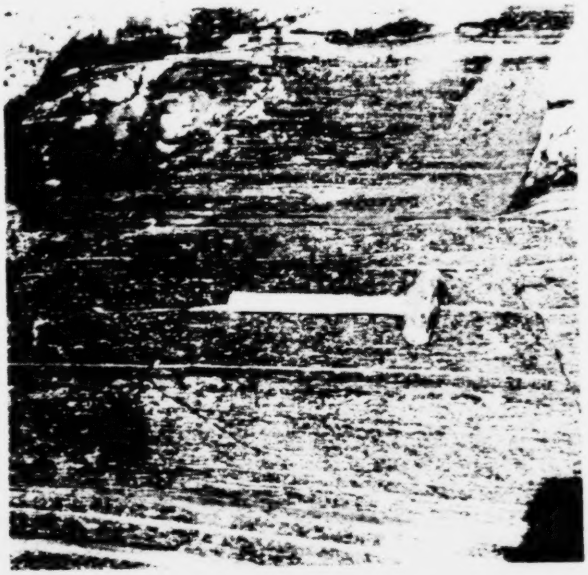

Plate 13: *Protomylonite and mylonite from shear zone in the Burgeo Granite.*

The regional metamorphism of the Bay du Nord Group accompanied the D_1 deformation, and occurred under greenschist to upper amphibolite conditions. In general, metamorphic grade increases with proximity to the synkinematic granites, and, in several areas, a structurally downward gradation occurs from middle greenschist facies metasedimentary rocks into sillimanite-bearing paragneiss and migmatite (O'Brien and Tomlin, 1984; Blackwood, 1984).

The second deformation locally produces large scale F_2 folds that are upright and plunge to the west and northwest (Blackwood, 1984). Smaller scale F_2 folds (Plate 14), parasitic on larger structures, are common. Axial planar to these folds is a regional foliation, which varies in intensity from a weak crenulation cleavage to a strong composite fabric produced by transposition of S_1. The S_2 strain-slip fabric in the Bay du Nord Group adjacent to the North Bay Granite post-dates the thermal metamorphism within the aureole; locally, fine grained biotite is developed along S_2 (Blackwood, 1983).

Plate 14: *F_2 refolding of isoclinal F_1 folds producing Type 3 interference patterns in quartz-injected pelite, Bay du Nord Group.*

The structural and metamorphic history of the La Poile Group is not clearly understood, and its structural style is variable within the Burgeo map area (Chorlton, 1980; O'Brien, 1983). The structure of the eastern, dominantly clastic portions of the La Poile Group is relatively simple, with few regional-scale folds and only a weakly developed fracture cleavage; metamorphic grade varies from lower to middle greenschist facies. The sedimentary rocks are progressively metamorphosed with proximity to the synkinematic granite terrane. A gradation is developed from quartzose sandstone and quartz-pebble conglomerate, through biotite-grade recrystallized psammite and quartz-rich conglomerate, into sillimanite-bearing paragneiss, (containing recognizable quartz clasts) and migmatite. Westward, the La Poile Group narrows to a 2 to 3 km wide belt that intervenes between the synkinematic granite terrane to the south and a major mylonite zone to the north (Chorlton, 1980). In this region, Chorlton (1980) described the development of second-generation folds of an early foliation and also tight third-generation folds. The Bay d'Est Fault, a major mylonite zone, separates amphibolite facies rocks of the Bay du Nord Group in the north from greenschist facies rocks of the La Poile Group.

MINERALIZATION

Mineralization within layered and massive gabbros of probable ophiolitic origin appears to be of minor significance. Two small pyrite showings consist mainly of mineralization along fractures in the gabbro; another showing contains minor malachite and associated arsenopyrite. All occurrences are within gabbros near Pig's Head, in the White Bear River (11P/14) map area (O'Brien and Tomlin, 1984).

Volcanic rocks of the Bay du Nord Group are host to a significant sulfide occurrence in altered massive rhyolite near Grey Lake, in the western part of the White Bear River map area (Barry, 1980; O'Brien and Tomlin, 1984). The largest occurrence contains disseminated chalcopyrite, pyrite and arsenopyrite. Rhyolite tuff approximately 500 m north of this occurrence also contains traces of pyrite. These showings are significant in that they occur at the same stratigraphic level as the Strickland massive sulfide deposit to the southwest (Cooper, 1954; Swinden, 1981), namely, within the uppermost part of the Bay du Nord volcanic succession, immediately below graphitic pelites and slates. Other very minor pyrite showings also occur along strike at a similar stratigraphic level in the White Bear River map area, and northeast of Top Pond (O'Brien and Tomlin, 1984). In the Peter Snout (11P/13) map area, felsic volcanic rocks, intercalated with pelitic schist and phyllite, are host to several small pyrite showings and a more significant occurrence of disseminated chalcopyrite, galena and sphalerite (O'Brien, 1983). In light of the recent gold discovery by BP Selco in lithologically similar rocks at Cinq Cerf Brook (McKenzie, 1985), areas underlain by the felsic volcanic rocks of the Bay du Nord Group should be considered as important targets for gold exploration. Gold potential may also exist within and adjacent to the Baggs Hill Granite (Tuach, *this volume*) and other subvolcanic intrusions in the area.

The Bay du Nord Group sedimentary rocks, especially the slates and pelitic schists, contain numerous minor pyrite occurrences (Scott and Conn, 1950; Barry, 1980; O'Brien, 1983). Pyrite, with minor scheelite and arsenopyrite, is reported to occur in quartz veins in sedimentary rocks from the northern parts of the White Bear River map area (see Scott and Conn, 1950; Smyth, 1979).

Extensive silicification, with minor associated sulfide mineralization in the contact zone of the Roti Granite (Chorlton, 1980) in the Peter Snout map area, is hosted by both the LaPoile Group and the granite (J. Tuach, personal communication, 1985). It may be part of a large epithermal-fumerolic system (cf. Tuach, *this volume*) similar to that seen in the Cinq Cerf Brook area.

Mineralization within the Baie d'Espoir Group is most extensive within the Isle Galet Formation. Mineralization is stratabound and consists of Pb-Zn-Cu massive sulfide occurrences in felsic tuff within pelite. These occurrences are discussed in some detail by Swinden (1980) and Colman-Sadd and Swinden (1982). The felsic volcanic and altered units within the Bay d'Espoir Group are currently the subject of active gold exploration. This activity is based mainly on a correlation of the Baie d'Espoir Group with the La Poile Group to the west. Gold has been discovered in the Baie D'Espoir Group, along strike to the northeast at Kim Lake and Le Pouvoir (McHale, 1985).

Recently discovered uranium mineralization in the Bay du Nord Group is stratiform in nature and is interpreted to be essentially syngenetic (O'Brien and Tomlin, 1985). The mineralization is present, locally, where felsic volcaniclastic rocks are interbedded with fine grained pelitic metasedimentary rocks. In places, the uranium appears to have been remobilized from the volcanic rocks into the overlying pelites. Within the unwelded tuffs, uranium is concentrated in the coarser grained, more porous zones. Some of the uranium has been remobilized during subsequent deformation and metamorphism of the pelitic rocks. It is possible that further remobilization of uranium has occurred during intrusion of the nearby late syntectonic granites.

In the Peter Snout map area, Shell Canada Resources discovered uranium mineralization in the Baggs Hill Granite and in numerous boulders and outcrops of fine grained metasedimentary rocks and feldspathic schist of the Bay du Nord Group. The company has reported radioactivity up to 30,000 c.p.s. (Urtec UG-130) from the Bay du Nord Group in that area, and several samples contain greater than 2,000 g/t U (Wells, 1981). It was thought that the uranium mineralization was related to the intrusion of the Devonian Peter Snout Granite, and that uranium was remobilized from originally uraniferous sediments by heat associated with the intrusion (Wells, 1981). Recent investigations indicate that although some of the mineralization is granite related, still more is stratabound and may be originally syngenetic (O'Brien and Tomlin, 1985).

The late-syntectonic to posttectonic granitoids in the Burgeo map area, such as the Ironbound monzonite, Cochrane Pond Granite, North Bay Granite, Chetwynd Granite and Francois Granite, locally display granophile element mineralization (Sn, W, U, Mo) or indications of enrichment in such elements.

The Ironbound monzonite is highly radioactive throughout. Whole rock geochemistry samples have been collected,using a grid system, and analyses are currently in progress. The uranium potential is greatest in this pluton, it being the most radioactive of all granites in the Burgeo map area. The Cochrane Pond Granite contains minor scheelite mineralization (Scott and Conn, 1950; Barry, 1980). The muscovite-tourmaline-lepidolite-garnet granite phase is relatively radioactive and also contains molybdenite mineralization. The granite is an obvious exploration target for tin-tungsten mineralization; extensive glacial drift has so far hindered a thorough examination. The North Bay Granite contains small scheelite showings within the Burgeo map area. These occur as joint fillings associated with tourmaline, and in pegmatite veins northeast of East Bay.

Numerous tungsten showings were discovered by the Buchans Mining Company during the 1950's in the contact zones between the Bay du Nord Group and the North Bay and Burgeo granites. The mineralization apparently occurs within the metasedimentary rocks as disseminated scheelite.

The Francois Granite and Chetwynd Granite are high-level, high-silica granites with a good potential for granophile element mineralization. McConnell (1984) has reported anomalous tin, lead and tungsten values from the Francois Granite. An airborne gamma-ray survey (Geological Survey of Canada, 1983) has indicated that the entire Francois Granite is highly anomalous, with the greatest anomaly in the ring complex north of Rencontre Bay. Unpublished whole rock analyses by the Department of Mines and Energy in this area indicate a high background U content of over 20 g/t. Minor greisen veins occur within the Francois Granite, but these apparently lack tin and tungsten mineralization.

The Chetwynd Granite is currently being examined geochemically and the potential for mineralization should be clarified following completion of the analyses. Although the Chetwynd Granite can be classified as a high-silica granite (SiO_2 = 70 to 78 percent, unpublished data), it does not exhibit the overall extreme differentiation seen in the Francois Granite. However, the lithological and tectonic similarities between the Chetwynd Granite and the Francois and Ackley granites to the east indicate a high potential for tin, tungsten and molybdenite mineralization.

Tungsten with minor fluorite, barite and base metals is hosted by quartz veins at Grey River (Bahyrycz, 1957). The mineralized hydrothermal vein system, apparently related to late granitoids (Higgins, 1980), is developed mostly in an amphibolite unit of the Grey River enclave. The veins vary in width from 2 cm to 1 m; the larger veins can locally be traced for 400 m. They follow north to northeast-trending fissures, which cross-cut the regional foliation in the country rocks. Wolframite is the most important tungsten mineral; scheelite is subordinate. Other ore minerals include pyrite, chalcopyrite, arsenopyrite, molybdenite sphalerite, galena, bismuth and marcasite. Fluorite and calcite occur as gangue minerals along with quartz. The vein system was offset by several east-trending normal faults, and later was cut by a series of tensional veins containing fluorite, calcite, barite, sphalerite, galena, apophyllite and harmotome (Higgins, 1980). The central portion, some 600 m in length, is considered to be potential ore with an average grade of 1 percent WO_3 over 1 m (Fogwill, 1970).

TECTONIC EVOLUTION AND SYNTHESIS

The earliest stage in the evolution of the region involved the generation of massive and layered gabbro associated with pyroxenite and peridotite. The present chemical database is not yet sufficient to establish their exact tectonic affinity. These rocks may be vestiges of either an ocean basin, a small marginal basin, or the roots of an immature remnant arc.

A major episode of Middle Ordovician volcanism and accompanying sedimentation is manifested by the Bay du Nord and Baie d'Espoir groups. The volcanism was almost exclusively silicic in nature, possibly indicating the involvement of continental crust in magma generation. The subaerial volcanism and fluvial sedimentation of the La Poile Group may represent not only Middle Ordovician volcanicity,

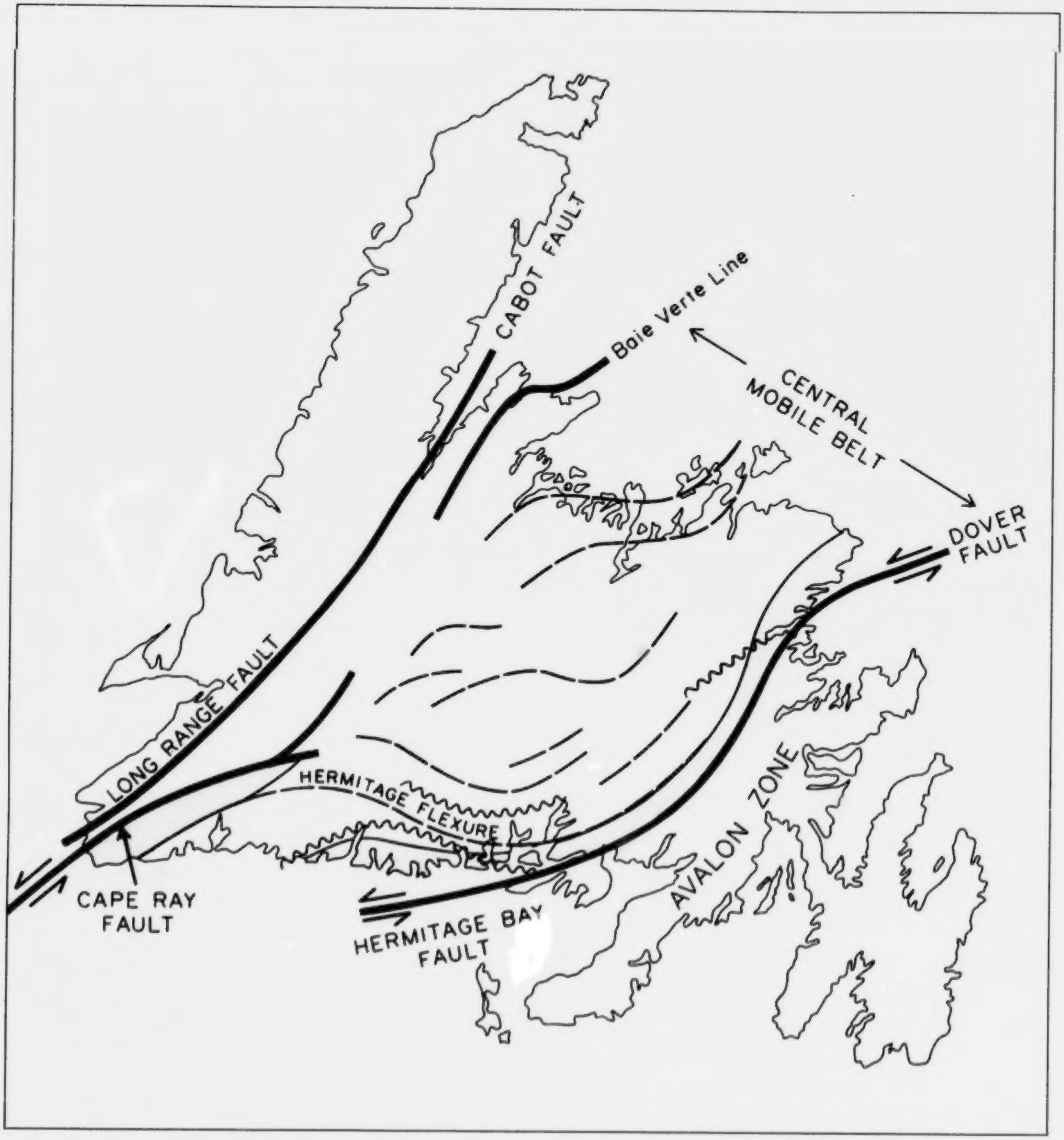
CABOT FAULT
Baie Verte Line
CENTRAL MOBILE BELT
DOVER FAULT
LONG RANGE FAULT
HERMITAGE FLEXURE
AVALON ZONE
CAPE RAY FAULT
HERMITAGE BAY FAULT

Figure 4: *The Dover-Hermitage Bay Fault and the Cape Ray Fault, interpreted as major, sinistral, wrench-fault systems that resulted in the clockwise rotation of the Central Mobile Belt, producing the Hermitage Flexure and subsidiary flexures in central Newfoundland. The shaded areas represent the general distribution of migmatites in the Gander Zone adjacent to the boundary faults (after Blackwood, 1985).*

but also significantly younger volcanic activity, unrelated to the Bay du Nord and Baie D'Espoir groups. Initial results from ongoing isotopic studies indicate that at least part of the La Poile Group is Silurian in age, and that either Grenville-aged continental crust or sediments derived from it was involved in melting to produce the La Poile magmas (G. Dunning, written communication, 1985).

The Baie d'Espoir Group is dominated by fine grained clastic sediments that were deposited in a quiet marine basin, distal to a volcanic centre (Swinden, 1982; Blackwood, 1985b). Sporadic volcanicity occurred throughout much of the group's depositional history. The Bay du Nord Group records an initial episode of extensive silicic volcanism, of probable submarine origin, followed by widespread, marine, clastic sedimentation (O'Brien, 1983; O'Brien and Tomlin, 1984; Blackwood, 1984). In the west, the proportion of volcanic rocks is higher than in the east; this may reflect westward proximity to a major volcanic centre. Sedimentary facies are variable and locally include rocks deposited in shallow restricted basins, probably contemporaneously with the main volcanic episode. Elsewhere, shelf facies environments pass into deeper water, turbidite-basin environments. Intercalated graphitic pelite and volcanic interbeds indicate intermittent periods of restricted deposition and sporadic silicic volcanism. The presence of debris flows and coarse grained conglomerates, locally containing foliated detritus, indicates relative proximity to an uplifted volcanic edifice. The La Poile Group, in the Burgeo map area, is tentatively interpreted to represent a subaerial volcanic centre, likely a caldera, that has an apron to the east of fluvial sedimentary rocks deposited in a fan-delta environment.

A major tectono-thermal event affected the region in the Silurian. The first period of deformation produced recumbent or locally upright folds. A regional penetrative foliation is developed axial planar to these structures, and in places merges into major D_1 mylonite zones. Throughout most of the volcanic-sedimentary succession of the area, metamorphic grade increases southward (structurally downwards), culuminating in migmatite zones that are intruded by synkinematic granitoids. Upright folds with an axial planar foliation of variable intensity formed in response to the second period of deformation.

The synkinematic (D_1) granitoids are complex, multiphase plutons that locally contain early components of quartz diorite, tonalite and granodiorite, which are rich in gabbroic inclusions. The association of the mafic rocks with these granitoids suggests a genetic link between them. The syn D_1 granitoids could have been produced during early subduction and associated metamorphism and deformation of the lower parts of the Ordovician arc successions in the Hermitage Flexure area. The possible role of continental crust in the production of these granites is uncertain. The syn D_2 granites are mainly muscovite- and biotite-bearing leucogranites, which in places may be related to progressive partial melting of peraluminous parental material, such as the stratified rocks of the Hermitage Flexure area.

Blackwood (1985b) has interpreted the Hermitage Flexure as a fundamental feature of the axial region of the Newfoundland Appalachians that formed in response to wrench faulting along the margins of the Central Mobile Belt. The orientation of the Hermitage Flexure implies a rotation of structural elements consistent with sinistral movements along the Dover-Hermitage Bay Fault and the Cape Ray and Long Range faults (Figure 4). In such a model, the southward-facing convexity of the eastern portion of the Hermitage Flexure would be the result of counterclockwise, external rotation of elements (c.f. Wilcox, *et al.*, 1973) along the Dover-Hermitage Bay Fault. The same sense of movement along the Cape Ray Fault would produce the southward-facing concavity of the western portion of the Hermitage Flexure. The overall effect of counterclockwise rotation along both wrench-fault systems would be to produce a clockwise rotation of structural elements in the medial region. Such a sense of rotation is mirrored by the Z-shaped flexures developed throughout the Central Mobile Belt.

The tectonic and plutonic style of the Burgeo map area is characteristic of the Hermitage Flexure area, and the Gander Zone as a whole. It is possible that much of the structural style is related to compression associated, at least in part, with shearing along the Dover-Hermitage Bay and Cape Ray faults (Blackwood, 1985b). Crustal thickening and associated increase in ambient temperatures, followed by subsequent uplift along the boundary faults, would result in the metamorphic pattern seen along the Hermitage Flexure. Metamorphism associated with the thermal relaxation of a thickened crust and subsequent melting of the lower crust, could have produced granitoids. Since melting in the crust can continue for up to 100 Ma after initial crustal thickening (e.g., Chamberlain and England, 1985), it is possible that the heat source for the younger granitoids could have originated during the Silurian D_1 tectono-thermal event.

The Burgeo map area and the entire Hermitage Flexure area are host to numerous mineral occurrences associated with each of the major stages in the geological evolution of this part of southwestern Newfoundland. Major gold discoveries in the Chetwynd and Cape Ray areas further serve to demonstrate the important economic potential of rocks along the Hermitage Flexure.

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GEOLOGY OF THE ST. JOHN'S AREA, NEWFOUNDLAND

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ABSTRACT

Late Precambrian (Hadrynian) rocks of the St. John's peninsula form the most easterly land exposures of the Avalon Zone in the Appalachian Orogen. Fault-bounded pillow basalt and metatuff of the Harbour Main Group define the western boundary of the map area. Metatuff along Broad Cove River is conformably overlain by a thick marine sequence of volcaniclastic turbidites, submarine debris flows, and distal argillaceous turbidites of the Conception Group. Distinctive water-lain tuffs define the top of the Conception Group in the central part of the area and are conformably overlain by dark-gray shale, black shale containing discontinuous 'slump' beds of sandstone, and gray sandstone of the St. John's Group. The shale-sandstone sequence represents a shoaling of the Conception basin by a turbidite-fronted, southward-prograding delta. Subsequent fluvial deposition gave rise to green and red sandstones and conglomerates of the Signal Hill Group, in response to major uplift north of the present Avalon Peninsula.

The map area is divisible into six main structural zones. The rocks indicate a long history of volcanism, uplift, subsidence and progressive deformation. The effects of Acadian deformation appear dominant; the effects of the late Precambrian Avalonian Orogeny are enigmatic.

INTRODUCTION

Mapping of the bedrock geology and surficial deposits of 500 km² in and around the City of St. John's at 1:12,500 scale was undertaken during 1985, under contract with the Mineral Development Division of the Newfoundland Department of Mines and Energy. The contract area, shown in Figure 1, bounded by north latitudes 47° 27', and west longitudes 52° 37' and 52° 53' ('the map area'), comprises eleven Newfoundland Department of Forest Resources and Lands 1:12,500 map sheets (0252; 0253; 0255; 0256; 0259; 1251; 1254; north half of 0258 and 1257; south half of 0288 and 0289), and eight NTS 1:25,000 map sheets (IN/10L; IN/10b, a; IN/7f; IN/7g; south half of IN/10G; east half of IN/10d and IN/7e).

Although the late Precambrian and Paleozoic rocks of the Avalon Peninsula have been studied for over 100 years, suprisingly, the St. John's peninsula has received sporadic attention and little is known about the volcanic and volcaniclastic stratigraphy, particularly of the Harbour Main and Conception groups, which underlie approximately two-thirds of the area. The only previously published large scale geological maps specifically of the St. John's peninsula are those of Rose (1952) at 1:253,440 scale and Hsu (1975) at 1:50,000 scale. An account of the previous geological work is given in King (1982).

The purpose of the present study is to document the distribution, origin and tectonic development of the late Precambrian lithofacies, and to provide a data base for subsequent hydrogeological and geotechnical investigations. This preliminary report outlines the main lithofacies. It is noteworthy that this survey represents the first, systematic, detailed, regional mapping and division of the late Precambrian Harbour Main, Conception, St. John's, and Signal Hill groups in the map area since they were subdivided in the southern Avalon Peninsula by Williams and King (1979).

Field Program

The coastal geology was investigated in some detail and inland traverses were run from roads and rivers and along tracks, trails, and transmission lines. Quarries, trenches, water-sewer lines and various other excavations were examined and sampled. A helicopter was used to map the inaccessible coastal cliffs north of Portugal Cove and south of Torbay Point. A canoe was used on ponds and lakes. Color aerial photographs (1:12,500 scale) were particularly useful in determining structural trends. Initial maps were plotted at a scale of 1:12,500 and at 1:5,000 for the Torbay-Outer Cove area. In total, 1,600 site descriptions of bedrock and surficial deposits have been completed. There is a close correlation between bedrock lithology and dominant clast type in till, indicating that the till veneer is of local origin, commonly less than 2 km from the source.

Geological Setting

The St. John's peninsula is part of the Avalon Zone (Williams, 1976). Relatively unmetamorphosed late Precambrian volcanic rocks (Harbour Main Group), together with turbiditic siliceous siltstones and sandstones (Conception Group), basinal-deltaic shales and sandstones (St. John's Group), and molasse-like clastic sedimentary rocks (Signal Hill Group) are locally overlain by Cambrian and Ordovician marine-shelf sedimentary rocks, and define major elongate structural domes and basins, (e.g., Williams and

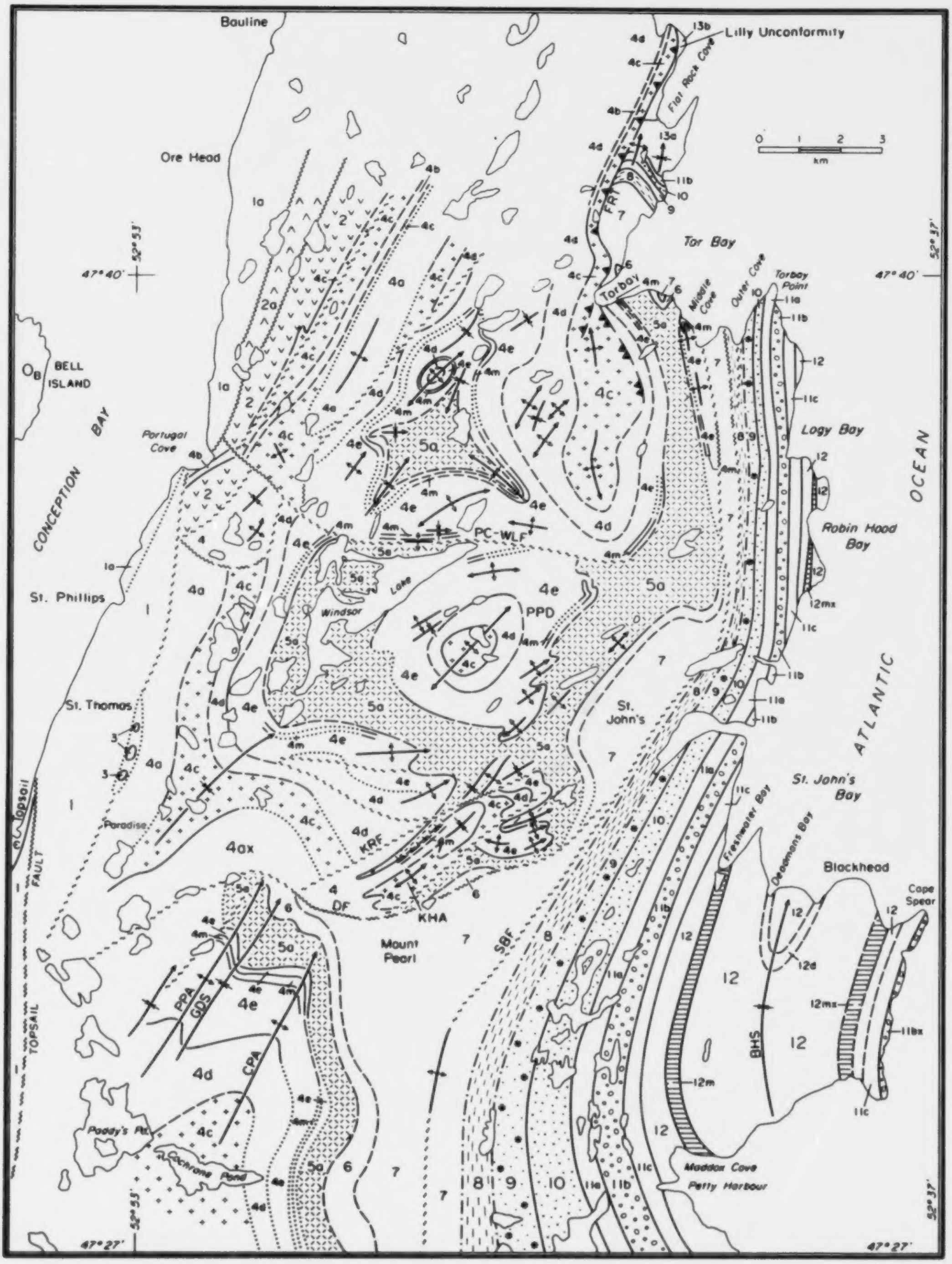
Bauline
Lilly Unconformity
13b
Flat Rock Cove
13a
0 1 2 3
km
Ore Head
Tor Bay
47° 40'
52° 55'
52° 37'
Torbay
Middle Cove
Outer Cove
Torbay Point
OB BELL ISLAND
Logy Bay
OCEAN
CONCEPTION BAY
Portugal Cove
Robin Hood Bay
PC-WLF
Windsor Lake
St. Phillips
PPD
St. Thomas
St. John's
ATLANTIC
St. John's Bay
Topsail Fault
Paradise
Freshwater Bay
Deadmans Bay
KRF
Blackhead
Cape Spear
DF
KHA
Mount Pearl
SBF
PPA
GDS
CPA
BHS
Paddy's Pd.
Cochrane Pond
Maddox Cove
Petty Harbour
TOPSAIL
47° 27'
1a
2a
4ax
12mx
11bx

Figure 1: *Geology of the St. John's area*

LEGEND

ORDOVICIAN	
OB	**BELL ISLAND GROUP:** Sandstone, shale, ironstone
CAMBRIAN	
Є	**ADEYTON AND HARCOURT GROUPS:** Shale
HADRYNIAN	
SIGNAL HILL GROUP (Units 9 to 13);	Latest Vendian to possibly early Paleozoic
12, 13	**Blackhead (12) and Flat Rock Cove (13) Formations:** red and gray sandstone, siltstone, mudstone, conglomerate and breccia.
12d	*Deadmans Bay member,* green mudstone and sandstone.
12m	*Maddox Cove member,* red mudstone and sandstone.
12mx	Red sandstone and mudstone (possible equivalent of Maddox Cove Member).
13b	*Piccos Brook Member,* locally derived breccia, red sandstone and mudstone.
13a	*Knobby Hill Member,* gray conglomerate and sandstone.
11	**Cuckold Formation:** red conglomerate and sandstone.
11c	*Petty Harbour member,* pebble conglomerate, fining upward into coarse grained sandstone.
11b	*Logy Bay member,* cobble and pebble conglomerate containing exotic clasts.
11bx	*Cape Spear member,* cobble conglomerate containing exotic clasts (probable equivalent of Logy Bay member).
11a	*Cabot Tower member,* pebble conglomerate and coarse grained variegated sandstone.
10	**Quidi Vidi Formation:** red and green fine to medium grained sandstone, minor pebble conglomerate and mudstone.
9	**Gibbett Hill Formation:** thick bedded greenish-gray sandstone, locally greenish-gray siltstone, tuff and conglomerate, minor red sandstone and siltstone.
ST. JOHN'S GROUP (Units 6 to 8);	Probably Vendian (670-590 Ma)
8	**Renews Head Formation:** thin lenticular bedded, dark rusty-gray sandstone and shale.
7	**Fermeuse Formation:** gray to black shale, contorted shale and sandstone, and thin bedded sandstone toward base.
6	**Trepassey Formation:** medium to thin bedded, graded, gray sandstone and shale, minor tuff.
CONCEPTION GROUP (Units 4 and 5);	Probably Vendian (670-590 Ma)
5	**Mistaken Point Formation** *upper-part:* variegated tuffaceous shale and sandstone of Hibbs Hole member. *lower part:* medium bedded, graded, tuffaceous, fossiliferous sandstone (gradational into Halfway Cove member).
5a	*Hibbs Hole member,* medium to thick bedded, red, purple and green tuffaceous shale, siltstone and argillaceous sandstone (gradational into Trepassey Formation).
4	**Drook Formation:** greenish-gray siliceous sandstone, siltstone and tuff.
4e	*Halfway Cove member,* laminated to medium bedded, greenish-gray and red, siliceous siltstone and tuffaceous sandstone; locally fossiliferous. Distinctive marker beds (map unit 4m) of red water-lain tuff and white vitric tuff near top of member.
4d	*Mannings Hill member,* white to yellowish-green weathering, intercalated, thick siliceous sandstone, siltstone and graded tuffaceous sandstone.
4c	*Torbay member,* streaky, laminated, coarse grained sandstone. Locally intercalated with Mannings Hill and Bauline Line members.
4b	*Bauline Line member,* volcanogenic mixtite (possible northern facies of Gaskiers Formation tillite).
4a	*Broad Cove River member,* greenish-gray chert and volcaniclastic sandstone.
4ax	*Paradise member,* gray to green chert (stratigraphic position uncertain; possible equivalent of Broad Cove River member).
HARBOUR MAIN GROUP (Units 1 to 3);	Possibly Late Riphean (1000-670 Ma)
3	**Dogberry Hill gabbro:** fine to coarse grained gabbro (age uncertain).
2	**Portugal Cove formation:** basaltic pillow lava.
2a	*Blast Hole Ponds member,* metabasalt and tuff; minor granite.
1	**St. Phillips formation:** green metatuff, agglomerate, mafic lava and siliceous volcaniclastic sedimentary rocks, includes rhyolitic and gabbroic to diabasic intrusive rocks.
1a	*Beachy Cove member,* strongly deformed and disrupted beds of siliceous volcaniclastic sedimentary rocks, basalt, rhyolite, tuff and agglomerate, includes rhyolitic and gabbroic to diabasic intrusive rocks.

King, 1979; King, 1980, 1982; O'Driscoll and King, 1985). The Precambrian rocks are intruded by granitoids of the 620 Ma Holyrood granite that are noncomformably overlain by Cambrian shales. The rocks were first deformed in the late Precambrian and subsequently regionally deformed and metamorphosed during the middle Paleozoic Acadian Orogeny. An account of the tectonic significance of the Avalon Zone of Newfoundland is given in O'Brien *et al.* (1983) and in King and O'Brien (*in press*).

GENERAL GEOLOGY

Formational Nomenclature

The Harbour Main Group (Rose, 1952) is provisionally divided into two new formations, St. Phillips and Portugal Cove, which are subdivided into the Beachy Cove and Blast Hole Ponds members respectively. Prominent gabbro plugs are here referred to as the Dogberry Hill gabbro. These represent the first formational divisions of this group.

The Conception Group nomenclature is essentially that of Williams and King (1979). The Drook Formation is provisionally subdivided here into six new members, Paradise, Broad Cove River, Bauline Line, Torbay, Mannings Hill, and Halfway Cove. During the field mapping, the Mistaken Point Formation was subdivided into a lower and upper part, the latter informally referred to as the Hibbs Hole member, a presumed correlative of the Hibbs Hole Formation (Hutchinson, 1953) at Conception Bay South.

The St. John's Group divisions are those of Williams and King (1979). These include, in ascending stratigraphic order, the Trepassey, Fermeuse and Renews Head formations.

The Signal Hill Group nomenclature of Williams and King (1979) is retained with minor modification. The Cuckold Formation of the Signal Hill Group is subdivided into three new members, which in ascending order are Cabot Tower, Logy Bay and Petty Harbour; a fourth member, Cape Spear, is probably a correlative of the Logy Bay member. The Blackhead Formation is subdivided into five parts, two of which are the Maddox Cove and Deadman's Bay members; three remain unnamed.

Lithostratigraphy and Structure

The St. John's peninsula east of the Topsail Fault (Figure 1) is divisible into six main tectonostratigraphic zones, each with its own distinctive rock types and structural style. The principal distinguishing characteristics of the various formations and members are shown in the Legend for Figure 1; their vertical and lateral variations are summarized in Figures 2 and 3.

Zone 1. This zone (map Units 1, 1a, 2a, eastern Conception Bay), bounded by an eastern splay of the Topsail Fault, consists of highly deformed metatuffs (St.Phillips formation) which are associated with strongly deformed, siliceous, sedimentary rocks and mafic volcanic rocks (Beachy Cove member). Metamorphosed pillow basalt and tuff (Blast Hole Ponds member) to the north of Portugal Cove is a possible correlative of the St. Phillips formation. Associated granitoid rocks (Holyrood Intrusive Suite?) are boudinaged, but younger plugs and dikes of gabbro (Dogberry Hill) and felsite occur along a fault marking the eastern boundary of the zone, and are for the most part undeformed.

Zone 2. This zone (map Units 2, 2a, Portugal Cove area) consists of fault-bounded blocks of massive and pillow basalt (Portugal Cove formation). Red argillite beds in the basalt exhibit open to tight folds. Stratigraphic top determinations in the argillite and pillows indicate much of the eastern margin of this zone, which is steeply dipping to the west, is overturned.

Zone 3. This zone (map Units 4a to 4e, Central St. John's peninsula) is in fault contact with Zones 1 and 2. It is characterized by siliceous volcaniclastic sedimentary rocks of the Drook Formation, the thickest and most extensive lithic unit in eastern Avalon Peninsula (Figure 2). Thick bedded greenish-gray chert and coarse grained volcaniclastic sandstone (map Unit 4a) are well exposed in Broad Cove River; the presence of rip-up clasts of tuff at the base suggests that this unit, the lowermost member of the Drook Formation, may disconformably overlie the St. Phillips Formation.

The cherts are conformably overlain by coarse grained arkosic sandstone (map Unit 4c) containing distinctive streaky laminae of siltstone and, locally, lenses and parallel laminae of silty sandstone, red tuff and orthoquartzite. This unit, provisionally named the Torbay member, is in part lithologically similar to coarse sandy facies of the Drook Formation associated with the Gaskiers Formation tillite at Cape English, southern Avalon Peninsula.

Along the Bauline Line, volcanogenic mixtite or diamictite (tillite?) is overlain by the Torbay member; elsewhere it is intercalated with thick units of streaky sandstone. The mixtite, provisionally named the Bauline Line member, may possibly represent a northern, coarse facies of the Gaskiers Formation.

The Torbay Member is overlain and locally intercalated with thick bedded siliceous sandstone, provisionally named the Mannings Hill member; excellent exposures occur at the Mannings Hill-Torbay Road intersection, opposite Torbay Post Office. Its white to yellowish-green weathering, gray to green and buff, siliceous sandstones, siltstones, argillites and cherts are the most widely recognized rock types that define the Drook Formation throughout the Avalon Peninsula (Williams and King, 1979).

The Mannings Hill member is conformably overlain by medium bedded siliceous sandstones and intercalated tuffs (map Unit 4e), provisionally named the Halfway Cove member (after a cove 'halfway' between Torbay and Middle Cove). A distinctive marker unit (Map Unit 4m) of red, waterlain tuff and white vitric tuff near the top of this member has been traced throughout the central part of the map area. Late Precambrian metazoan fossils were found immediately below and above the marker unit; the upper part of the Halfway Cove member is a possible correlative of the fossiliferous horizons identified in the type locality at Mistaken Point.

The various members of the Drook Formation are relatively competent rocks which form large scale domes and

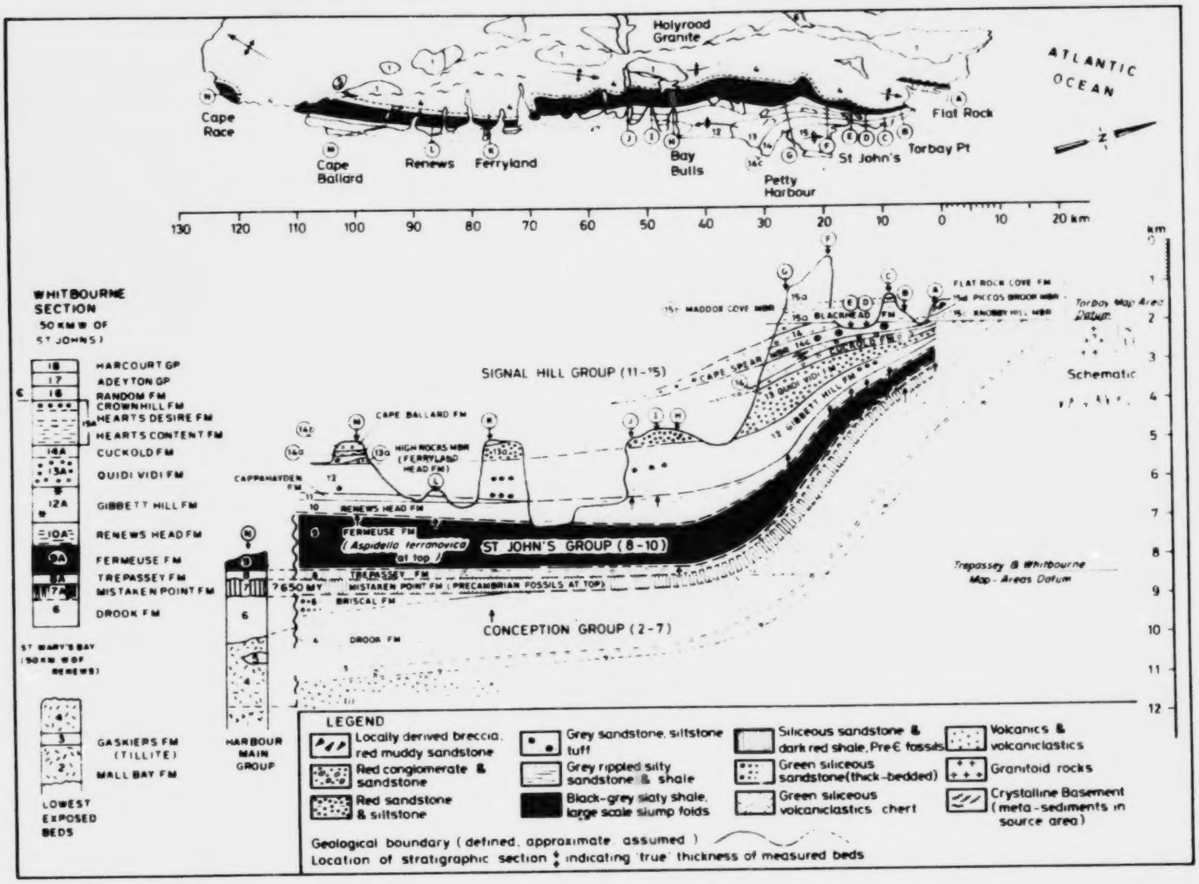
Holyrood Granite
ATLANTIC OCEAN
Cape Race
Cape Ballard
Renews
Ferryland
Bay Bulls
Petty Harbour
St John's
Torbay Pt
Flat Rock
N
130
120
110
100
90
80
70
60
50
40
30
20
10
0
10
20 km
km
WHITBOURNE SECTION
50 KM W OF ST JOHNS)
HARCOURT GP
ADEYTON GP
RANDOM FM
CROWNHILL FM
HEARTS DESIRE FM
HEARTS CONTENT FM
CUCKOLD FM
QUIDI VIDI FM
GIBBETT HILL FM
RENEWS HEAD FM
FERMEUSE FM
TREPASSEY FM
MISTAKEN POINT FM
DROOK FM
ST MARY'S BAY (50 KM W OF RENEWS)
GASKIERS FM (TILLITE)
MALL BAY FM
LOWEST EXPOSED BEDS
HARBOUR MAIN GROUP
SIGNAL HILL GROUP (11-15)
CAPE BALLARD FM
HIGH ROCKS MBR (FERRYLAND HEAD FM)
CAPPAHAYDEN FM
RENEWS HEAD FM
FERMEUSE FM (Aspidella terranovica at top)
ST JOHN'S GROUP (8-10)
TREPASSEY FM
?650 MY
MISTAKEN POINT FM (PRECAMBRIAN FOSSILS AT TOP)
BRISCAL FM
DROOK FM
CONCEPTION GROUP (2-7)
FLAT ROCK COVE FM
15d PICCOS BROOK MBR
15c KNOBBY HILL MBR
15b MADDOX COVE MBR
BLACKHEAD FM
CAPE SPEAR MBR
CUCKOLD FM
13 QUIDI VIDI FM
12 GIBBETT HILL FM
Torbay Map Area Datum
Schematic
Trepassey & Whitbourne Map-Areas Datum
LEGEND
Locally derived breccia, red muddy sandstone
Red conglomerate & sandstone
Red sandstone & siltstone
Grey sandstone, siltstone tuff
Grey rippled silty sandstone & shale
Black-grey slaty shale, large scale slump folds
Siliceous sandstone & dark red shale, Pre€ fossils
Green siliceous sandstone(thick-bedded)
Green siliceous volcaniclastics chert
Volcanics & volcaniclastics
Granitoid rocks
Crystalline Basement (meta-sediments in source area)
Geological boundary (defined, approximate, assumed)
Location of stratigraphic section ↕ indicating 'true' thickness of measured beds

Figure 2: *Stratigraphic profile of late Precambrian units, eastern Avalon Peninsula (modified after King, 1982).*

basins, corresponding with areas of topographic high and low relief. Windsor Lake, for example, is within a complex structural basin.

Zone 4. This zone (map Units 5 and 6, central to eastern St. John's peninsula) lies conformably above Zone 3 and is easily recognized by conspicuous red and green tuffaceous siltstones and sandstones (map Unit 5a), which are correlatives of the Hibbs Hole member, now regarded as the upper part of the Mistaken Point Formation. Thin bedded, turbiditic, argillaceous sandstone (map Unit 6) of the Trepassey Formation defines the top of the zone. Both of these argillaceous units are highly susceptible to frost action and are therefore only exposed in the low ground between intervening domes, where they display an intricate pattern of interference folds.

Zone 5. This zone (map Units 7 and 8, eastern St. John's peninsula) is a coarsening upward sequence, stratigraphically above and to the east of Zone 4; it consists of tightly folded Fermeuse Formation black shale (map Unit 7) and Renews Head Formation sandy shale (map Unit 8). Locally, where squeezed between competent units or where overthrust by competent units as in the Flat Rock thrust zone, Zone 5 pinches out tectonically.

Zone 6. This zone (map Units 9 to 13, eastern St. John's peninsula) is comprised of competent units of Gibbett Hill Formation green sandstone (Plate 1), Quidi Vidi Formation red sandstone (Plate 2), Cuckold Formation conglomerate (Plates 3 and 4; Figure 4), Blackhead Formation sandstone and mudstone (Plate 5) and Flat Rock Cove Formation conglomerate, sandstone and breccia. These units, although vertically persistent, show lateral variations in thickness, composition, and texture (Figure 2).

The Signal Hill Group rocks are the least deformed of the zones and throughout eastern Avalon Peninsula display broad, large scale, open folds, such as exemplified by the Blackhead Syncline.

STRUCTURAL GEOLOGY

Tectonic Setting

Two periods of deformation have been identified in eastern Avalon Peninsula: (1) an enigmatic Late Riphean to Vendian (Cadomian or Pan-African) orogenic episode, named the 'Avalonian' by Rodgers (1972) and first described as the 'Avalonian Orogeny' by Lilly (1966); (2) a major Siluro-Devonian (circa 395 Ma) disturbance, viz. the 'Acadian Orogeny'.

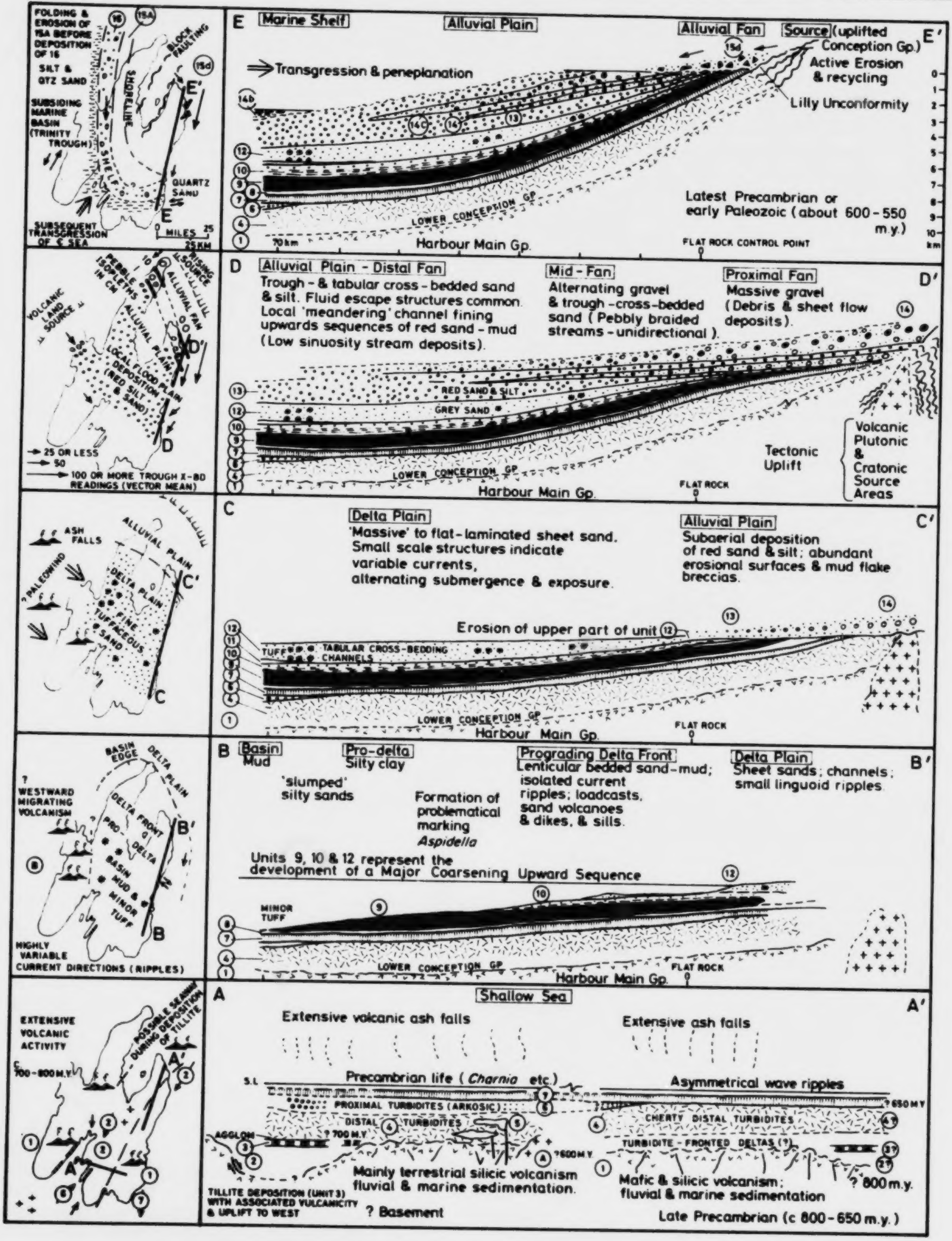
FOLDING & EROSION OF 15A BEFORE DEPOSITION OF 16
16
15A
SILT & QTZ SAND
BLOCK FAULTING
SHORELINE
15d
SUBSIDING MARINE BASIN (TRINITY TROUGH)
E'
SHELF
QUARTZ SAND
SUBSEQUENT TRANSGRESSION OF € SEA
E
MILES 25
25KM
E
Marine Shelf
Alluvial Plain
Alluvial Fan
Source (uplifted Conception Gp.)
E'
Transgression & peneplanation
Active Erosion & recycling
Lilly Unconformity
14b
14c
14
13
15d
12
10
9
8
7
6
4
1
LOWER CONCEPTION GP
Harbour Main Gp.
70km
FLAT ROCK CONTROL POINT
Latest Precambrian or early Paleozoic (about 600 - 550 m.y.)
0
1
2
3
4
5
6
7
8
9
10
km
PEBBLE ISOPLETHS IN CM
RISING SOURCE
VOLCANIC LAND SOURCE
ALLUVIAL FAN
ALLUVIAL PLAIN
D'
LOCAL FLOOD PLAIN DEPOSITION (RED SILT & SAND)
D
25 OR LESS
50
100 OR MORE TROUGH X-BD READINGS (VECTOR MEAN)
D
Alluvial Plain - Distal Fan
Trough - & tabular cross - bedded sand & silt. Fluid escape structures common. Local 'meandering' channel fining upwards sequences of red sand - mud (Low sinuosity stream deposits).
Mid - Fan
Alternating gravel & trough - cross - bedded sand (Pebbly braided streams - unidirectional).
Proximal Fan
Massive gravel (Debris & sheet flow deposits).
D'
14
13
12
10
9
8
7
6
4
1
RED SAND & SILT
GREY SAND
LOWER CONCEPTION GP
Harbour Main Gp.
FLAT ROCK
Tectonic Uplift
Volcanic Plutonic & Cratonic Source Areas
ASH FALLS
ALLUVIAL PLAIN
? PALEOWIND
DELTA PLAIN
C'
FINE TUFFACEOUS SAND
C
C
Delta Plain
'Massive' to flat - laminated sheet sand. Small scale structures indicate variable currents, alternating submergence & exposure.
Alluvial Plain
Subaerial deposition of red sand & silt; abundant erosional surfaces & mud flake breccias.
C'
13
14
Erosion of upper part of unit 12
12
11
10
9
8
7
6
4
1
TUFF
TABULAR CROSS-BEDDING
CHANNELS
LOWER CONCEPTION GP
Harbour Main Gp.
FLAT ROCK
BASIN EDGE
DELTA PLAIN
? WESTWARD MIGRATING VOLCANISM
DELTA FRONT
B'
PRO - DELTA
BASIN MUD & MINOR TUFF
8
B
HIGHLY VARIABLE CURRENT DIRECTIONS (RIPPLES)
B
Basin
Mud
'slumped' silty sands
Pro-delta
Silty clay
Formation of problematical marking *Aspidella*
Prograding Delta Front
Lenticular bedded sand - mud; isolated current ripples; loadcasts, sand volcanoes & dikes, & sills.
Delta Plain
Sheet sands; channels; small linguoid ripples.
B'
Units 9, 10 & 12 represent the development of a Major Coarsening Upward Sequence
12
10
9
MINOR TUFF
8
7
6
4
1
LOWER CONCEPTION GP
Harbour Main Gp.
FLAT ROCK
EXTENSIVE VOLCANIC ACTIVITY
POSSIBLE SEAWAY DURING DEPOSITION OF TILLITE
c. 700 - 800 M.Y.
A'
2
1
2
3
A
1
6
7
A
Shallow Sea
A'
Extensive volcanic ash falls
Extensive ash falls
S.L.
Precambrian life (*Charnia* etc.)
Asymmetrical wave ripples
7
6
PROXIMAL TURBIDITES (ARKOSIC)
? 650 M.Y.
4
DISTAL TURBIDITES
5
CHERTY DISTAL TURBIDITES
4 ?
AGGLOM
3
2
? 700 M.Y.
4
? 600 M.Y.
TURBIDITE - FRONTED DELTAS (?)
3 ?
2 ?
1
Mainly terrestrial silicic volcanism fluvial & marine sedimentation.
Mafic & silicic volcanism; fluvial & marine sedimentation
? 800 m.y.
TILLITE DEPOSITION (UNIT 3) WITH ASSOCIATED VULCANICITY & UPLIFT TO WEST
? Basement
Late Precambrian (c 800 - 650 m.y.)

Figure 3: *Late Precambrian and Early Paleozoic development of the Avalon Peninsula (Legend as for Figure 2).*

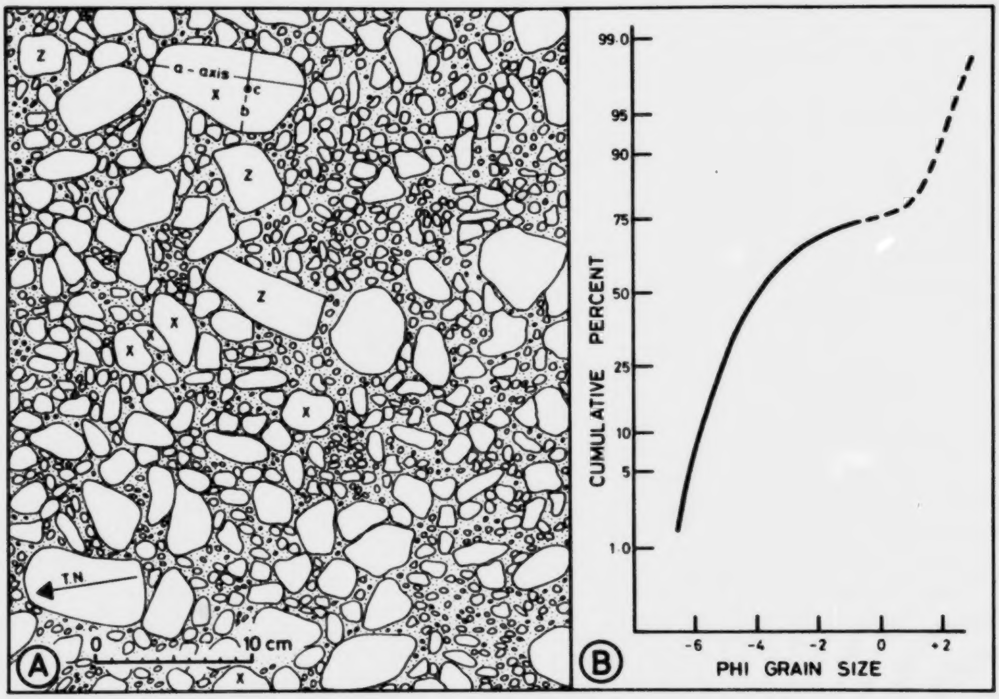

Figure 4: *Clast and matrix variations in the Cape Spear Member, Cuckold Formation, Cape Spear.*

A. Plan view of conglomerate bedding surface showing clasts of rhyolite, tuff, quartz-sericite schist (x), and vein quartz (z) in a poorly sorted matrix. C-axis of largest clast is approximately 4 cm.

B. Grain size cumulative curve for coarsest stratigraphic level in Cape Spear Member. Sample area 2 m± by 5 cm thick.

The effects of the late Precambrian Avalonian Orogeny are enigmatic. Pre-Tommotian unconformities in widespread localities throughout the Avalon Peninsula provide evidence of mainly Vendian folding, block-faulting, granitoid emplacement (620 Ma Holyrood Intrusive Suite) and general crustal instability, e.g., Lilly Unconformity, Figures 2 and 3. The present concentric arrangement of late Precambrian sedimentary rocks around a volcanic core in the eastern Avalon appears to be the result of Precambrian structural doming, since Lower Cambrian strata overstep the Conception Group to lie directly upon the Holyrood granite and Harbour Main Group volcanic rocks at Conception Bay (McCartney, 1967).

The effects of Acadian deformation and metamorphism in the Avalon Zone of Newfoundland are dominant but variable, reflecting the heterogeneity of the Acadian event. Metamorphism in eastern Avalon Peninsula occurred under prehnite-pumpellyite facies conditions (Papezik, 1973).

Major Tectonic Elements

The Precambrian rocks of the map area provide evidence of several phases of progressive deformation. The earliest phase is observable in the Mount Pearl - Kenmount Hill area. It is characterized by tight to isoclinal folds and associated strike-slip and thrust faults that have been refolded about north-northwest to northeast-trending axes. The latest phase of deformation is assumed to relate to the Acadian Orogeny in which continued compression produced major open folds with steep axial surfaces and a coplanar cleavage. Examples are the gently northward plunging Paddy's Pond and Cochrane Pond anticlines and the Glendale and Blackhead synclines.

The Kenmount Hill anticlinorium provides evidence of multiple progressive deformations. It is a complex horst-like block of tightly folded Drook Formation strata; both early folds and associated faults within the block are refolded or warped about a major northerly trending axis. It is possible that the younger open folds resulted from warping and southward detachment of the block above a resistant basal unit, as may be provided by the Harbour Main Group volcanic rocks. Black shales of the St. John's Group exposed along Waterford River are separated from the block by the Donovans fault, and are warped around the southern end of the Kenmount Hill anticlinorium. A steeply dipping, north-northwest-trending slaty cleavage is well developed in the Fermeuse Formation in the Mount Pearl area and is possibly a product of the younger folding phase.

The South Brook Fault Zone extends from Outer Cove, through downtown St. John's, to the Goulds. It consists of a north-northeast-trending, 100 to 1000 m wide zone of tightly

Plate 1: *Low angle planar cross-stratification in Gibbett Hill Formation, Petty Harbour Road.*

Plate 3: *Exotic clast of quartz-sericite schist, Logy Bay member, Cuckold Formation, Logy Bay; clast maximum diameter is 6 cm.*

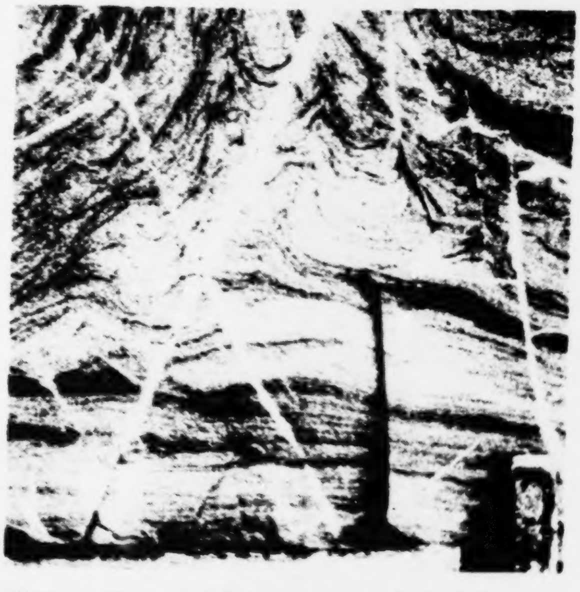

Plate 2: *Thixotropic deformation in Quidi Vidi Formation, Petty Harbour Road.*

Plate 4: *Alternating red sandstone and pebble conglomerate interpreted as mid-fan deposit; Petty Harbour member, Cuckold Formation, Cape Spear.*

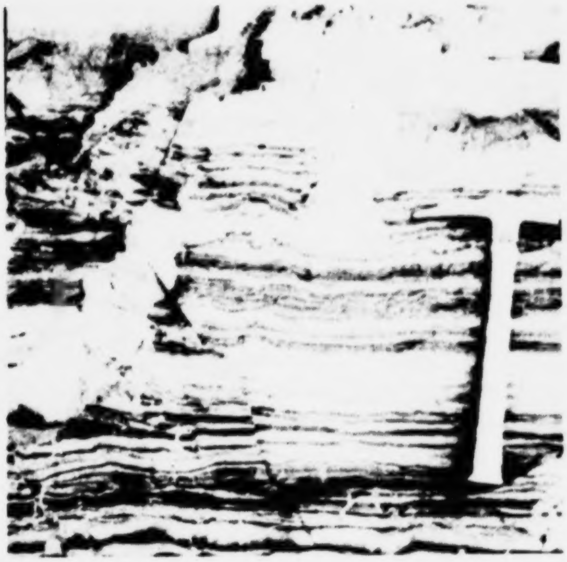

Plate 5: *Alternating thin red sandstone and mudstone, cut by sandstone dikes, Maddox Cove member, Blackhead Formation.*

folded, faulted and disrupted strata of the Fermeuse Formation. This zone resulted from intense compression and rupture of incompetent shales between relatively competent Conception Group sandstones within the domes to the west, and Signal Hill Group sandstones and conglomerates within the Blackhead Syncline to the east.

The Donovans Fault trends parallel to the Waterford River in the Donovans-Mount Pearl area and is interpreted to branch into two or more splay faults northeast of Mount Pearl. This fault is poorly exposed in the map area, except for local zones of intense fracturing, brecciation and massive quartz veining; its trace, however, at Donovans and along most of its length is marked by structural discontinuity, with the southern side downthrown.

The northeast-trending Kenmount Road fault is a narrow (up to 100 m wide) fault zone that defines the northern margin of the Kenmount Hill anticlinorium. Closely spaced and steeply northwest-dipping faults are exposed at several localities along its length. It is interpreted as a pivotal normal fault with the north side downthrown; slickensides and rock plucking along the fault surface indicate normal or down-dip movement.

The Portugal Cove - Windsor Lake Fault is a sinistral strike-slip fault with an oblique-slip component. Pillow basalts of the Portugal Cove formation are clearly offset by this fault in the vicinity of Portugal Cove.

Minor Tectonic Elements

Numerous joint sets and fracture zones are evident in virtually all rock units present in the map area. Joint systems are especially well developed in thick bedded sandstones and comglomerates of the Signal Hill Group.

Rhombohedral joints are characteristic of the Signal Hill Group and developed perpendicular to the stratification probably during early stages of folding. A fourth penetrative joint set (dip 15 to 35°N) in the Gibbett Hill Formation is filled with white quartz and minor pale-green prehnite, and traces of calcite, pyrite and pyrolusite. This set can be traced from Petty Harbour to Torbay Point. Some joint sets contain amethyst and copper minerals (O'Driscoll and King, 1985).

Open fracture zones, i.e., closely spaced, highly interconnected, discreet fractures, are characteristic of the siliceous Drook Formation. Iron (derived from weathered pyrite, hematite and magnetite) and manganese (pyrolusite) are common stains along fracture surfaces, indicating that fracture zones and, to a lesser extent, bedding surfaces are the primary conduits for groundwater movement in these otherwise well cemented, low matrix-porosity rocks.

Steeply dipping fractures and slaty cleavage are characteristic of the more argillaceous bedrock units such as the Mistaken Point, Trepassey, Fermeuse, and Renews Head formations. The north-northwest trending slaty cleavage in the Fermeuse Formation in the Newtown - Mount Pearl area provides a conduit for groundwater movement and the migration of iron and manganese.

PALEOGEOGRAPHIC EVOLUTION

Schematic diagrams of the proposed evolution of the Avalon Peninsula, shown in Figure 3, are based on regional studies by King (1980, 1982, 1984) and are applicable to the Precambrian rock units in the map area. They reflect a long history of volcanic activity, uplift and subsidence.

Facies relationships indicate an early history of widespread marine turbidite and pelagic sedimentation (Conception Group) around an active volcanic archipelago (Harbour Main Group). The St. John's Group black shales record a shoaling of the marine basin, and then southward-prograding deposition of deltaic sands of the Gibbett Hill Formation (Plate 1). Local tuff beds in the Drook and Mistaken Point formations diminish upward in the St. John's Group and record waning volcanic activity. Tuff beds in the Gibbett Hill and overlying formations of the Signal Hill Group record intermittent deposition of volcanic ash. The presence of tuff and ash beds in the Signal Hill Group indicate comtemporaneous sporadic volcanic activity, possibly related to the Bull Arm Formation volcanism which originated to the west of the Avalon Peninsula. It is noteworthy that mafic and felsic volcanic rocks which formed mainly in a subaerial environment between circa 630 and 570 Ma are widespread throughout the entire eastern margin of the Appalachians. This period was also a time of Precambrian, Avalonian tectonic movements. In eastern Newfoundland, a rising mountain front on the northern periphery of the present Avalon Peninsula gave rise to alluvial plain conditions, now represented by red sandstone (Quidi Vidi Formation), conglomerate (Cuckold Formation) and variegated sandstones and mudstones (Blackhead Formation), all of which constitute a molasse-like sequence resulting from tectonic upheaval (Plates 2 to 5).

Rock fragments and constituent detrital minerals indicate that the Signal Hill Group was derived largely from a source area underlain by rocks of the Harbour Main and Conception groups and the Holyrood Intrusive Suite. However, the Gibbett Hill Formation also contains small amounts of detrital garnet and muscovite (Papezik, 1973); this, together with exotic clasts in the Logy Bay and Cape Spear members (Plate 3) and the northeasterly provenance of the Signal Hill Group sediments, may indicate the presence of crystalline basement rocks on the continental shelf to the northeast of the Avalon Peninsula.

ACKNOWLEDGEMENTS

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EXPLORATION GEOCHEMICAL STUDIES OF LABRADOR GRANITOIDS

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INTRODUCTION

Field work during 1985 involved the collection of a variety of sample materials for geochemical analyses from granitoid terranes in Labrador. Work was done in five areas (Figure 1) which are considered to have high potential for hosting granite-related mineralization, such as Sn, W, REE, Nb, Be and Zr. Sample media include rock, soil, stream sediment/water, and lake sediment/water. The quantity and type of samples collected in each area are summarized in Table 1. Surficial samples will be analyzed for some, or all, of the following elements and variables: Ag, Ba, Be, Ce, Co, Cu, F, Fe, La, Li, Mo, Mn, Nb, Ni, Pb, Rb, Sn, Sr, Ta, Th, U, W, Y, Zn, Zr, loss-on-ignition and pH. Rocks will also be analyzed for major and minor elements.

Table 1: Location, type and quantity of samples collected during 1985.

Area	Rock	Lake Sediment and Water	Stream Sediment and Water	Soil
Letitia	4	203		209
Flowers River	347			239
Michikamats	10	123		
13L/13	7	23	14	
Anaktalik	5	67	3	

AREA DESCRIPTIONS

Letitia Lake Anomaly

The area is underlain by peralkaline gneisses and volcanic rocks. Previously known mineralization includes occurrences of Be, Nb, Th, Zr and REE. Results of a recent reconnaissance lake sediment and water survey from this area indicated high concentrations of Pb, F and Zn (Geological Survey of Canada, 1983). Analyses of F and Zn in samples of lake water collected this summer during a detailed lake survey revealed three highly anomalous areas within the broader regional anomaly. Two of these contain previously known mineralized outcrops and boulders. Soil samples (B horizon) were collected from a 9 x 11 km grid in the third area, in the course of which several boulders of radioactive gneiss were found.

Flowers River Area

The Flowers River Igneous Suite, consisting of felsic volcanic rocks intruded by peralkaline granite, is one of three known peralkaline complexes in Labrador. As such, it represents a possible host for various types of mineral deposits. Previous geological mapping (Hill, 1982) and geochemical studies (McConnell, 1984) located occurrences of Be, F, Zr, Nb, Y, Pb, and Zn. A systematic, high density (1 sample per 4 km^2) rock and soil-sampling survey of the intrusive phases was made during the 1985 field season, based on Hill's 1:100,000 mapping. Geochemical and lithological studies of these samples will be made, in an effort to recognize areas of geochemical zoning and/or alteration on which mineral exploration could focus.

Michikamats Lake Anomaly

This area is distinguished in the reconnaissance lake data by very high levels of fluoride in water and moderately high levels of molybdenum in sediment (Geological Survey of Canada, 1978b). The area is underlain by Paleohelikian granite and syenite and is without known mineralization. Lake sediment/water samples and some representative rock samples were collected from an area of 280 km^2.

13L/13 Anomaly

This small area (65 km^2) is distinguished in the reconnaissance lake data by very high F and U concentrations in both water and sediment (Geological Survey of Canada, 1983). The bedrock is granite and typically has 1.5 to 3 times higher than average total count scintillometer readings. Lake sediment/water, stream sediment/water and rock samples were collected.

Anaktalik Brook Anomaly

This anomaly is reflected in the reconnaissance lake water data (Geological Survey of Canada, 1978a) by very high fluoride concentrations, similar to values associated with the Strange Lake Alkaline Complex 100 km to the west, which hosts a large tonnage deposit of Y, Nb, Zr, Be and REE. Lake sediment and water samples and a few stream sediment and rock samples were collected from an area of 140 km^2. Fluorite was observed in some outcrops of granite. Unfortunately, the lake sediment samples from this anomaly were destroyed by fire before any analyses were done.

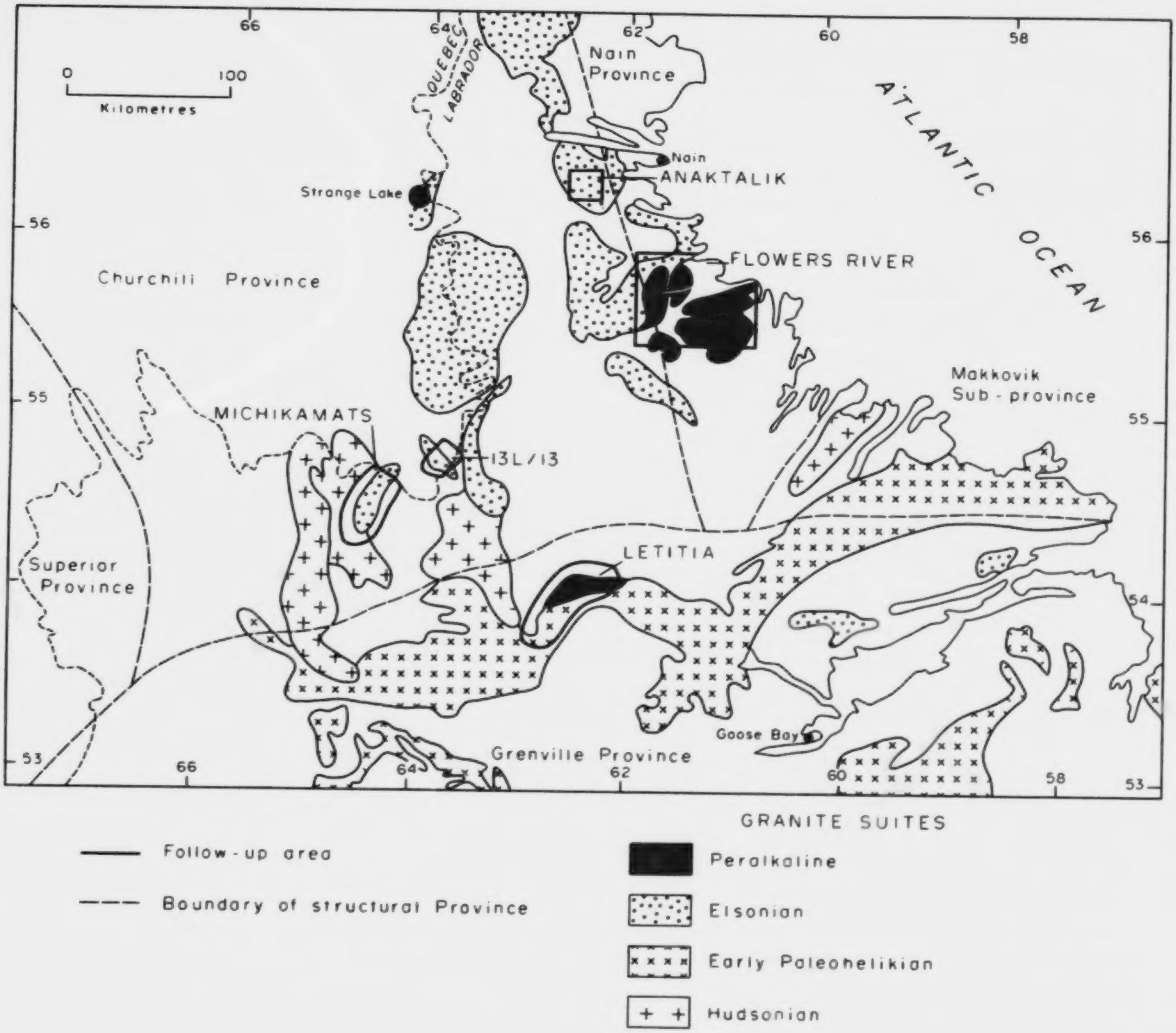
66
64
62
60
58
0 100
Kilometres
QUEBEC
LABRADOR
Nain Province
Nain
ANAKTALIK
ATLANTIC OCEAN
Strange Lake
56
Churchill Province
FLOWERS RIVER
Makkovik Sub-province
55
MICHIKAMATS
13L/13
LETITIA
Superior Province
54
Goose Bay
Grenville Province
53
GRANITE SUITES
Follow-up area
Boundary of structural Province
Peralkaline
Elsonian
Early Paleohelikian
Hudsonian

Figure 1: *Location of follow-up areas and granitoid geology of central Labrador.*

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GEOCHEMICAL FOLLOW-UP SURVEYS, LABRADOR TROUGH

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INTRODUCTION

Follow-up geochemical surveys were conducted in three areas of Labrador during the 1985 field season (Figure 1). One area was northeast of Wabush-Labrador City known as Rannie Lake (A), and two other areas were in close proximity to Schefferville, Quebec: Iron Arm (B) to the east and Howell's River (C) to the west.

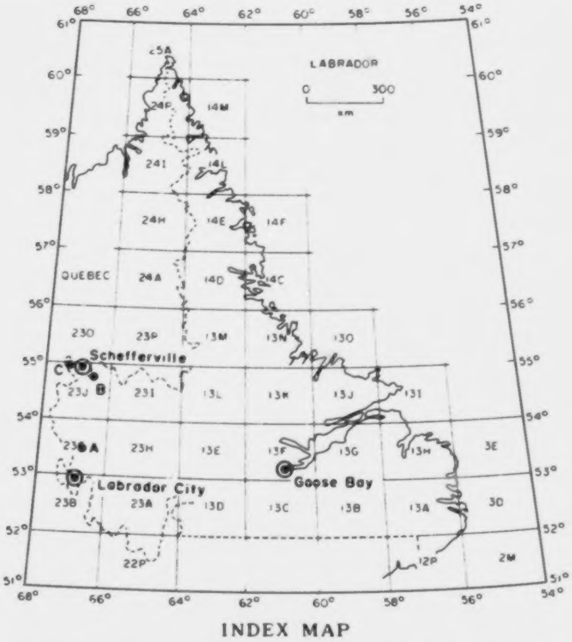

Figure 1: *Areas of geochemical follow-up in the Labrador Trough.*

AREA DESCRIPTIONS

Rannie Lake Area (A)

Previously known as Anomaly 6 (McConnell, 1984), the anomalous zinc area at Rannie Lake was shown to extend southward from the original anomaly based on reconnaissance lake sediment data (Geological Survey of Canada, 1982). Initially, lake sediment and lake water samples were collected from the 230 km² area at a density of 1 sample per 1.8 km². This was followed by sediment sampling every stream within the area at a sample interval of 50 m. In all, 137 lake sediment samples and 261 stream sediment samples were collected.

The area is covered with glacial overburden to a considerable depth. Eskers are common throughout the northern part of the area, some reaching a height of almost 10 m. Only three outcrops were noted in the northwest corner of the area, the largest of which is a north striking ridge that is exposed for a distance of about 50 m. The rock type in this outcrop is homogeneous Menihek Formation shale containing very minor quartz veins.

Iron Arm Area (B)

The Iron Arm area is about 30 km east of Schefferville. In 1981, John McConnell completed a detailed soil sampling program in the area. Soil samples were collected every 50 m from a grid with a 2 km baseline and 2 km crosslines 400 m apart. Our work extended the baseline for 1 km to the west and added crosslines at 400 m intervals on the extension. In addition, three lines, each 500 m long, were run off both sides of a small lake which intersected line 19+50W at 5+82S. A total of 136 soil samples were collected from the grid extension. The original grid and the extension were also surveyed for rock samples. A total of 83 rock samples from outcrop, probable outcrop and local float were collected.

All samples were analysed for a suite of elements including Cu, Pb, Zn, Co, Ni, Ag, Mn, Fe, F, Cd and loss on ignition. Some selected samples may be analysed for other elements such as Au at a later date. The data will be released on open file when all analyses and statistics have been completed.

Howell's River Area (C)

The Howell's River area is located west of the town of Schefferville, Quebec, and extends to the northwest. Several of the lake sediment samples collected during the URP surveys (Geological Survey of Canada, 1979) produced anomalous values in zinc. During the 1985 field season, lake sediment and lake water samples were collected, and then stream sediment samples were taken. From an area of about 800 km², there were 207 lake water and lake sediment samples and 285 stream sediment samples collected.

The Howell's River area contained much less glacial overburden than the Rannie Lake area and outcrops were noted at several localities along both the north and south sides of Howell's River. All outcrops were highly fractured, relatively homogeneous, Menihek Formation shale; minor pyrite occurs locally. Some rock samples were collected for analysis.

Affiliated Work

Joan Tod conducted geophysical work in two of the three areas discussed above. At Rannie Lake, a grid was established and VLF-EM, magnetic and scintillometer readings were recorded. The second grid was established over, and at an angle to, a grid originally established by McConnell in 1980 (McConnell, 1984) at Iron Arm. On this grid, VLF-EM and magnetic readings were recorded. The results of the geochemistry and geophysics will be incorporated into a joint open file release in 1986.

ACKNOWLEDGEMENTS

The field crew for this season were Allan Galay (senior assistant), Margot Davis, Louise Daley and Rick McDonald. All did an excellent job, both in the field and with camp chores. Margot, in particular, is thanked for her three years of dedicated work on the island and in Labrador. Universal Helicopters (Nfld.) Ltd. provided excellent helicopter service, ably piloted by Jeff Maloney and maintained by Barry Sheppard. Sid Parsons, Ted Hall and Dave Warren assisted with logistics on the island and Wayne Tuttle is thanked for his assistance with difficult logistics in Labrador.

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Current Research (86-1) Newfoundland Department of Mines and Energy, Mineral Development Division, Report 86-1, pages 223-237

REGIONAL GEOCHEMICAL PATTERNS IN THE EASTERN CENTRAL MINERAL BELT OF LABRADOR

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and

Peter Davenport
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ABSTRACT

This report describes some preliminary results from an interpretation of lake sediment and water geochemical data for the Central Mineral Belt of Labrador using a range of multivariate statistical procedures. The most important steps in data analysis are multiple linear regression, calculation of residuals and R-mode factor analysis with VARIMAX rotation. The regression and calculation of residuals are used to selectively remove the effects of inter-element correlations which are considered to be related largely to environmental factors such as lake depth, topography, drainage and a variety of limnological processes. Factor analysis is used to both reduce the volume of data and to group elements into associations influenced mostly by single factors, which can perhaps be interpreted in terms of rock associations or geologic processes such as mineralization. Regional geochemical patterns are illustrated with factor score distribution maps for a five factor model explaining 66 percent of the total variance, and an attempt is made to interpret some of these patterns.

The results suggest that geological packages within the Central Mineral Belt have very distinct geochemical signatures, which can to some extent be correlated with what is known about their general geology and styles of mineralization. For example, the Archean gneisses show a signature suggesting enrichment in Ni,MgO and CaO, coupled with depletion in U and F, which is shared by Proterozoic granitoids that intrude, and were perhaps derived from these gneisses. In contrast, granitoid rocks of the younger Trans-Labrador batholith display enrichment in U, Mo, F, Pb and Zn, elements which are often indicators of granite-hosted mineralization.

On a more local scale, supracrustal rocks of the Moran Lake Group and perhaps also paragneisses within the Grenville Province are enriched in the base metals Cu, Co and Zn. This signature is not shared by the supracrustal sequences of the Bruce River Group and parts of the upper Aillik Group, which instead show enrichment in Ag, As and possibly Hg. The latter pattern is tentatively interpreted to indicate that these areas may have potential for precious metal mineralization. There appear also to be some differences between the geochemical signatures of the two separate outcrop areas of the upper Aillik Group. These may be due to the effects of late granites, but could also represent a difference in composition related to differences in tectonic setting or age.

INTRODUCTION

Project Description

Regional geochemical surveys in Labrador using lake sediment as a sample medium have been carried out over the last seven years under the Uranium Reconnaissance Program and several Canada- Newfoundland mineral development agreements. Analytical data for some of the more economically promising areas have only become available following the 1982 and 1983 programs. It is now possible for the first time to integrate data for entire structural or lithologic provinces, and it appears that Newfoundland and Labrador will be the first province to have complete reconnaissance geochemical coverage.

This report summarizes the results of an analysis of data for the eastern part of the Central Mineral Belt, an area which has been the focus of most past and present exploration work in Labrador. It was carried out as one of the initial stages of an ongoing project to investigate the petrology, geochemistry and mineral potential of granitoid rocks in this area, as a method of delineating areas that show favourable geochemical signatures within plutonic terranes. The results are, however, of interest also in terms of the regional geology of the Central Mineral Belt and its potential for a range of commodities, in particular Au and Ag.

General Geology

The Central Mineral Belt of Labrador (Greene,1974) was first defined by exploration geologists in the 1950's and consists of a west-trending zone of Aphebian and Helikian supracrustal sequences, which host a large number and variety of base-metal, uranium and rare-metal mineral occurrences. The Central Mineral Belt lies along the northern margin of

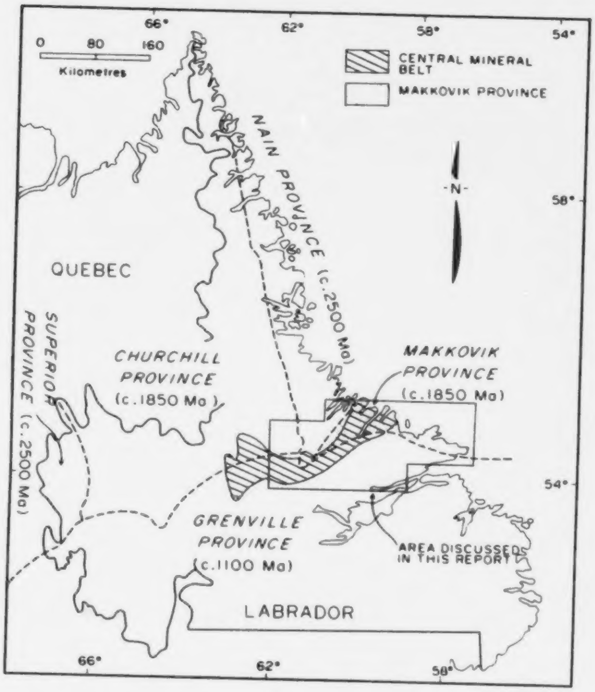
66°
62°
58°
54°
0 80 160
Kilometres
CENTRAL MINERAL BELT
MAKKOVIK PROVINCE
NAIN PROVINCE (c.2500 Ma)
-N-
58°
QUEBEC
SUPERIOR PROVINCE (c.2500 Ma)
CHURCHILL PROVINCE (c.1850 Ma)
MAKKOVIK PROVINCE (c.1850 Ma)
54°
GRENVILLE PROVINCE (c.1100 Ma)
AREA DISCUSSED IN THIS REPORT
LABRADOR
66°
62°
58°

Figure 1: *Location of the Central Mineral Belt of Labrador and the area discussed in this report.*

the Grenville Province (c.1.1 Ga) , but also partly overlaps the older Nain, Makkovik and Churchill structural provinces (Figure 1). The geology of the eastern part of the belt has been recently described by Gower (1981), Gower *et al.* (1982) and Ryan (1984), and the northern edge of the study area by Ermanovics and Raudsepp (1979), Ermanovics and Korstgard (1981) and Emslie (1980). The generalized geological map shown in Figure 2 was compiled from all these sources. The geology of the area is dominated by four major subdivisions of basement and supracrustal rocks, and at least 3 discrete groups of intrusive rocks. The basement and supracrustal rocks are:

1. Archean basement gneisses exposed in the northern part of the area, and consisting of banded to massive gray orthogneisses with intercalated amphibolite and metasedimentary units, intruded by a variety of foliated to gneissic granitoid rocks. In the east, much of this Archean block has been variably remobilized during early Proterozoic orogenic events.
2. Aphebian supracrustal rocks (Moran Lake and Aillik groups). The Aillik Group (exposed in the east) consists of a lower mafic volcanic and metasedimentary sequence and an upper thick felsic volcanic pile; the lower and upper sequences may possibly be separated by an unconformity. The Moran Lake Group (in the west) is lithologically similar to the lower Aillik Group and may be correlative with it.
3. Paleohelikian supracrustal rocks (Bruce River Group) consisting of sandstones and conglomerates overlain by mafic to felsic volcanic rocks that are thought to be subaerial. Rb-Sr data suggest an age of c.1.5 Ga, but an unpublished U-Pb zircon age (Krogh, personal communication to R.J.Wardle, 1985) suggests 1.65 Ga as an alternative.
4. Neohelikian supracrustal rocks (Seal Lake Group) consisting of a shale-quartzite-conglomerate sedimentary sequence with intercalated mafic volcanic and plutonic rocks. Rb-Sr ages suggest that it is c.1.32 Ga in age.

The three main groups of post-Archean intrusive rocks are:

1. Foliated to gneissose granitoids emplaced between 1.9 and 1.8 Ga, coincident with early Proterozoic orogenic events affecting Archean basement and Aphebian supacrustal rocks.
2. A largely posttectonic polyphase granitoid batholith (Trans-Labrador batholith) dated at c.1.65 Ga, although some portions may be correlative with, or younger than, the Bruce River Group.
3. Anorthosites and related granitoid rocks of the c.1.45 Ga Harp Lake Complex. The complex postdates the Bruce River Group but predates the Seal Lake Group.

In addition to the supracrustal and intrusive rocks listed above, large areas south of the Grenville Front are underlain by orthogneisses and paragneisses which are rather poorly known. Some of the orthogneisses may be deformed equivalents of the Trans-Labrador batholith.

ANALYSIS OF GEOCHEMICAL DATA

Overview of Data

The areas discussed in this report include NTS map sheets 13J and 13K, together with portions of 13O and 13I, and were sampled in 1977,1978 and 1983. Descriptions of sampling methods, media and analytical techniques were described by the Geological Survey of Canada (1981, 1984) and have also been reviewed by Davenport (1982) and McConnell(1984). The subset of the data used in this examination was selected by using coded geological information, based on the geological map of Greene (1974), to select only those sample sites underlain by the geological subdivisions described in the preceding section, with the exception of the Seal Lake Group. This resulted in a data file containing 1512 observations with the following variables: depth, pH, LOI, Zn, Cu, Pb, Ni, Co, Ag, Mn, As, Mo, Fe, Hg, U, F, $U(H_2O)$, $F(H_2O)$, V and Cd. Values for V and Cd are available only for about 46 percent of the observations , and Hg values include a number of missing cases. For this reason, these variables have been omitted from some of the later steps in statistical analysis. U and F were also measured in water, e.g., $F(H_2O)$ and $U(H_2O)$.

In order to deal with this large volume of data and present it in the form of a small number of maps, a number of statistical analysis methods were employed. The methods are relatively commonplace statistical procedures in a variety of fields, but the combinations and sequences in which they are

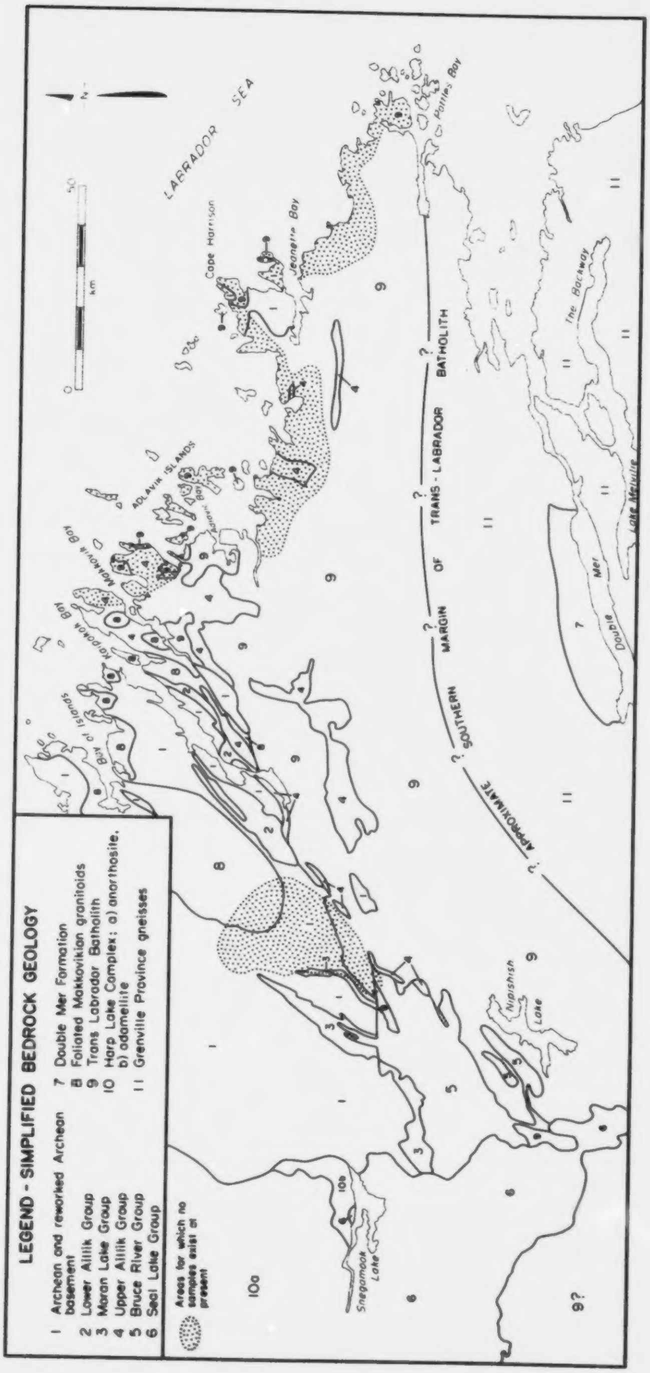
LEGEND - SIMPLIFIED BEDROCK GEOLOGY
1 Archean and reworked Archean basement
2 Lower Aillik Group
3 Moran Lake Group
4 Upper Aillik Group
5 Bruce River Group
6 Seal Lake Group
7 Double Mer Formation
8 Foliated Makkovikian granitoids
9 Trans Labrador Batholith
10 Harp Lake Complex: a) anorthosite, b) adamellite
11 Grenville Province gneisses
Areas for which no samples exist at present
LABRADOR SEA
0 km 50
N
Cape Harrison
Jeanette Bay
Pottles Bay
ADLAVIK ISLANDS
Makkovik Bay
Kaipokok Bay
Bay of Islands
Snegamook Lake
Nipishish Lake
The Backway
Lake Melville
Double Mer
APPROXIMATE ? SOUTHERN MARGIN OF TRANS - LABRADOR BATHOLITH
10a
9?

Figure 2: *Generalized geological map of the study area (after Gower, 1981; Gower et al., 1982; Emslie, 1980 and Ryan, 1984).*

applied were developed by P.H.Davenport and the geochemistry section as part of an overall project to produce geochemical atlases of the province (Davenport and Butler, 1983). Statistical calculations were performed using the SPSS computer package (Nie *et al.*, 1975). Maps that illustrate later portions of this report were produced initially as proportional symbol maps with a plotting program (MAPPLOT), and were subsequently hand contoured.

Data Analysis Methods

Data analysis can be divided into seven steps:

1. Generation of descriptive statistics (mean, minimum, maximum and standard deviation) to assess the characteristics of frequency distributions for all variables.

2. Log transformation of all variables where the standard deviation exceeds 0.5 of the mean value. This affects all variables except LOI and pH, which is already a logarithmic measurement.

3. Generation of a correlation matrix (Pearson type) to assess the magnitude and significance of inter-element correlations and, in particular, correlations that reflect the effects of variables whose distribution reflects mostly 'environmental', i.e., limnological, processes rather than the effects of bedrock geology.

4. Stepwise multiple linear regression analysis to generate equations relating the concentration of elements of economic interest to the concentration of these elements whose distribution reflects environmental factors.

5. Calculation of residuals for all elements whose regression equations suggest that a significant proportion of their variance is due to lacustrine environmental effects.

6. R-mode factor analysis[1] of regressed data, and assessment of factor models involving 4 to 7 factors (see explanation below).

7. Calculation of factor scores for all sample sites based on the preferred model, and generation of factor score distribution maps to represent the data.

The multivariate steps (4 and 6) have two main objectives. Step 4 allows the removal of variation which is considered largely to be of 'environmental' origin. Residuals represent the differences between the actual value of an element in samples and the values predicted by the regression equation. They are thus a much better indicator of bedrock effects than raw (unregressed) data. R-mode factor analysis seeks to group elements together on the basis of inter-element correlations and re-expresses the data in terms of a smaller number of new variables termed factors. This leads to a considerable reduction in the volume of data. The basic premise of the method is that variation in a multivariate data set is related to variations in the influence of a much smaller number of 'factors', which, in a geological context, could perhaps be thought of as particular rock types, mineralization styles or geological processes. It is possible, therefore, to use the results of factor analysis to identify the causes of variations in the data, but only by using subjective geological reasoning.

Although some of these concepts will be unfamiliar to many geologists, it is felt that the factor score maps can be understood and interpreted without detailed insight into the mathematics, and that the patterns themselves provide proof of the usefulness of the method in regional geochemical studies. A rigorous description of regression and factor analysis can be obtained from any comprehensive text on geostatistics, such as Davis (1973).

Analysis of Inter-Element Correlations

Table 1 is a correlation matrix showing Pearson correlation coefficients (R) for all variable pairs including Hg, V and Cd. The values of the coefficients may vary from 1.0 to -1.0 (such values reflect 'perfect' correlation, as for an element with itself) and indicate the magnitude and direction of correlation (negative values indicate antipathetic correlation). In the discussion that follows, correlations are categorized as strong where $R \geq 0.60$, moderate where R is between 0.45 and 0.60 and weak where R is between 0.30 and 0.45. Values less than 0.30 are not shown in Table 1 for the sake of clarity.

Several prominent associations can be discerned from Table 1:

1. Moderate correlations between depth and most other variables, with the exception of Pb,F, F(H_2O) and perhaps also As and Ag, which are marginal. A strong correlation, however, is present between depth and Mn.

2. Strong correlations (>0.80) between Fe and Mn, Fe and Co and Mn and Co. These are accompanied by moderate to strong correlations between many variables and one or more of these three elements. The notable exceptions are Ag, U(H_2O), F(H_2O), pH and LOI.

3. Moderate to strong correlations among the base metals Cu, Zn, Ni and Co. For Cu and Ni, these correlations are higher than those with Fe and Mn.

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[1] In this report the term 'factor analysis' is used to describe procedures collectively contained in the FACTOR subprogram of SPSS (Nie *et al.*, 1975). The terms 'Principal Component Analysis' and 'Factor Analysis' are not interchangeable, but the methods are closely related and there is no clear concensus on terminology. Accordingly, those familiar with the methods should note that some statisticians would prefer the term 'Principal Component Analysis' for some of the techniques used here. For a full discussion of methods, see Nie *et al.*, 1975.

Table 1. Correlation Matrix for Central Mineral Belt Lake Sediment Data

	LOI	pH	DPTH	Zn	Cu	Pb	Ni	Co	Ag	Mn	As	Mo	Fe	U	F	U*	F*
LOI	1.00																
Ph	—	1.00															
DPTH	—	0.43	1.00														
Zn	—	0.38	0.52	1.00													
Cu	0.37	0.34	0.59	0.62	1.00												
Pb	—	—	0.32	0.40	—	1.00											
Ni	—	0.57	0.46	0.57	0.61	0.32	1.00										
Co	—	0.34	0.53	0.68	0.55	—	0.52	1.00									
Ag	0.40	—	0.42	—	0.43	0.32	—	—	1.00								
Mn	—	0.35	0.61	0.65	0.49	0.30	0.48	0.85	0.37	1.00							
As	—	0.46	0.43	0.40	0.42	0.35	0.45	0.44	0.32	0.52	1.00						
Mo	—	0.31	0.46	0.63	0.47	—	0.35	0.58	—	0.54	0.33	1.00					
Fe	—	—	0.52	0.69	0.47	—	0.36	0.84	—	0.83	0.37	0.61	1.00				
U	—	—	0.44	0.56	0.46	0.36	0.33	0.44	0.30	0.43	—	0.68	0.46	1.00			
F	-.34	—	—	0.42	—	0.42	0.33	0.42	—	0.44	0.33	0.33	0.45	0.38	1.00		
U*	—	—	—	—	—	—	—	—	—	—	—	—	—	0.48	—	1.00	
F*	—	—	—	—	—	—	—	—	—	—	—	—	—	—	0.35	0.49	1.00
Hg	0.66	—	0.45	0.37	0.53	—	0.32	—	0.53	0.30	—	0.30	—	—	—	—	—
Cd	—	0.48	0.39	0.62	0.56	—	0.48	0.34	0.36	0.37	0.36	0.30	—	—	—	—	—
V	—	—	—	0.42	—	—	0.24	0.69	0.33	0.69	0.37	0.49	0.81	0.39	—	—	0.35

NOTE: Values between 0.30 and -0.30 have been omitted for the sake of clarity.
* Measured In Lake Water

4. Generally moderate correlations between (Cu, Zn, Co) and (Mo, U). The individual correlations of these elements with Fe and/or Mn are generally of similar magnitude or higher than their inter-correlation.

5. Strong correlations between U and Mo, and moderate correlations between U and U(H_2O) and U(H_2O) and F(H_2O). Other correlations within this group of "lithophile" elements are generally weak.

6. Moderate correlation between pH and Ni.

7. Generally weak correlations between Pb and almost all other elements. The highest values are with Zn and F.

8. Very poor correlation between U(H_2O), F(H_2O) and most other elements. The U(H_2O) - F(H_2O) correlation is stronger than either the U(H_2O) - U or F(H_2O) - F correlations.

In a general sense, these results resemble those of McConnell(1984), who analyzed data for areas of Labrador sampled prior to 1982, excluding data for As, Hg, V and Cd. The strong correlations dominated by Fe/Mn/Co and depth are present in both analyses, as are base metal and U-Mo-F-U(H_2O)-F(H_2O) associations. However, negative correlations between LOI and other variables are not as evident for the Central Mineral Belt data, and the pattern of correlations is somewhat more complex. The latter observation most likely reflects the contrast between an aggregated data set based on 100 km² cells (McConnell,1984) and the 'noisier' raw data used in this study. Of the correlations described above, we ascribe 1, 2, and 4 to 'environmental' factors, which are related mostly to lacustrine processes, rather than primary bedrock associations. The effect of (Fe, Mn) an other element distributions has been documented by Davenport (1982), McConnell (1984) and in a large number of exploration geochemistry programs elsewhere, and is widely considered to represent a coprecipitation effect caused by Fe-Mn oxides and hydroxides whose unusual surface properties give rise to a 'scavenging' effect. Depth is thought to be involved indirectly in this effect as it influences Eh-pH conditions at the sediment-water interface, which in turn control the stability fields of the various Fe-Mn compounds. McConnell(1984) also pointed out that depth may correlate with a finer sediment fraction containing clays, which have high ion exchange capacities. Correlations noted in 4 are interpreted mostly to be secondary effects of the depth-Fe-Mn control.

LOI is primarily a measure of the organic content of the samples and may exert some effect on metal concentrations via adsorption. It is correlated weakly with Cu, Ag, and F (Table 1) and strongly (0.61) with Hg. As LOI variation is without doubt related to limnological processes, it should be considered in the next step in analysis.

The remaining important correlations (3,5 and 6) are considered to reflect variations in bedrock geochemistry. The base-metal association probably reflects a common geological association and similar mobility during surface processes (c.f. McConnell,1984). The Mo-U-F association may perhaps relate to evolved igneous rocks, as these elements are commonly enriched in silicic magmas that have undergone extensive fractionation.

A correlation between pH and Ni may be a reflection of more basic rock types, which have higher Ni contents and tend to underlie lakes whose pH is buffered at about 7.0. A similar correlation was noted by McConnell (1984), but it was accompanied by a negative correlation with $F(H_2O)$, which is not as marked in the Central Mineral Belt data. The lack of correlation between Pb and most other elements is less easily explained, but it is probably related to bedrock effects.

The above discussion suggests that 'environmental' effects are responsible for a significant amount of the variance in the Central Mineral Belt data. In order to 'see through' these effects to the underlying variations related to bedrock geology, their effects must be selectively removed by linear regression. The four variables Fe, Mn, depth and LOI are considered to be indicators of lacustrine environments and are thus chosen as the independant variables.

Regression Analysis and Calculation of Residuals

Results of regression analysis using Fe, Mn, depth, and LOI as independant variables suggest that a significant proportion of the variance of many other elements is of 'environmental' origin. The proportion is highest for Co and Zn, where over 50 percent of the variance is explicable via regression. Most other elements provide regression equations which account for 30 to 50 percent of their variance. For Ni, U, $U(H_2O)$, $F(H_2O)$ and Pb, less than 30 percent of the variance is explained by regression, and residuals were not calculated for these elements.

A *residual* is a measure of enrichment or depletion that is not explained by the regression, and hence (in these data) probably unrelated to environmental factors. For many elements, the residual populations are probably much better indicators of bedrock compositional variations than raw element data, and the significance of residuals is proportional to the amount of variance explained by the regression equations. The improvements offered by residuals can also be assessed by comparing maps showing raw and residual values for the area. In general, the latter are much smoother and easier to contour, and anomaly patterns commonly often differ significantly between the two, particularly with respect to the magnitude and size of anomalies. This tendency was also noted by McConnell (1984). In the discussions which follow, residual variables are indicated by a 'r' placed in front of the chemical symbol, e.g., rMo.

Factor Anlaysis

On the basis of the preceding steps in analysis, raw data for Co, Zn, Mo, Cu, As, F, and Ag were replaced by residual data. In order to group the elements for easier representation, the technique of R-mode factor analysis was used.

The most important result of factor analysis is a factor loading matrix, such as that shown in Table 2 for the Central Mineral Belt data. This shows the grouping of elements corresponding to particular factors, and indicates the magnitude and direction of their correlation. Definitions of 'strong',

Table 2. Factor Loading Matrix for 5-factor model with VARIMAX rotation.

	FACTOR 1	FACTOR 2	FACTOR 3	FACTOR 4	FACTOR 5	COMMUNALITY
U	0.80	—	—	—	—	0.74
rMo	0.78	—	—	—	—	0.66
U*	0.74	-.33	—	—	—	0.64
pH	—	0.82	—	—	—	0.75
Ni	—	0.71	—	0.39	—	0.75
F*	0.42	-.53	0.47	—	—	0.69
rF	—	—	0.79	—	—	0.66
Pb	—	—	0.72	—	—	0.63
rCu	—	—	—	0.80	—	0.73
rCo	—	—	—	0.67	—	0.53
rZn	—	—	0.35	0.65	—	0.59
rAg	—	—	—	—	0.85	0.75
rAs	—	0.34	—	—	0.53	0.47
% VE†	24.4	15.4	10.8	8.6	6.9	

NOTE: Values between 0.30 and -0.30 are omitted for the sake of clarity.
* Measured in lake water rather than sediment.
† Percentage of variance explained by this factor.

'moderate' and 'weak' are identical to those used for Table 1. The preferred model is the 5 factor model, which explains 66 percent of the total variance. Models with greater numbers of factors did not greatly improve this figure and started to generate factors which controlled single elements only. V, Cd and Hg were not included in factor analysis as the large number of missing cases causes problems in computation.

From the factor loading matrix , the factor scores for the sample sites can be calculated. The significance of scores for a particular factor can be assessed from the patterns in Table 2 . For example, a high score on factor 1 indicates that the sample is high in U, rMo, U(H_2O) and F(H_2O). High scores on factor 2 suggest depletion in U(H_2O) and F(H_2O) coupled with high pH and Ni values (negative loadings indicate antipathetic correlation). The immediate value of this step lies in a reduction of the *volume* of data involved, from 15 variables to only 5. A second advantage is that it is possible to ascribe geological significance to some or all of the derived factors and their score distributions.

DESCRIPTION AND INTERPRETATION OF REGIONAL GEOCHEMICAL PATTERNS

Figures 3 through 7 inclusive illustrate the distribution of factor scores for the 5 factors derived in Table 2. Factor scores are standardized variables, and are thus expressed in units of standard deviations. Contour intervals for each map are set at the 60th, 80th, 90th, and 95th percentiles and 'spot highs' (defined as single samples which are more than 2 contour intervals higher than all immediate neighbors) are eliminated for the sake of clarity at this scale. The simplified geological map in Figure 2 is at the same scale. It also illustrates the areas for which no sample data is available, including the mountainous areas along the coastal strip and swampy areas in major river valleys.

Implicit in the following discussion is the assumption that the characteristics of samples are influenced most strongly by the bedrock underlying the immediate drainage basin. Glaciation is also an important factor, as noted by McConnell (1984), but data on the Quaternary geology of Labrador is not yet sufficiently abundant to allow us to consider it in detail. However, we consider that bedrock effects are likely to be most important at the scale of this study, and the main effect of ice movements will be a 'blurring' of the relationship between geochemical response and bedrock units.

Factor 1 [U, U(H_2O), rMo, F(H_2O)]

Factor 1 shows strong positive loadings for three variables, U, rMo and U(H_2O) with lesser effects for F(H_2O). This general association is typical of fractionated silicic magmas enriched in large-ion lithophile elements and, for this reason, it is considered to be a 'granophile' factor. The general distribution of high factor 1 scores is in accordance with this conclusion. Most are along the northern margin of the Trans-Labrador batholith, and areas underlain by Archean gneisses, the Bruce River, Moran Lake and lower Aillik groups are generally low. The upper Aillik Group shows a more complex pattern. Some specific areas are discussed below.

The most prominent high forms a southeast-trending zone from Makkovik Bay to Adlavik Bay. This area is mostly underlain by upper Aillik Group volcanic rocks, but also contains a number of small granitoid bodies that host or are spatially related to Cu-Mo mineralization. A second high southwest of here shows a distribution that correlates generally with a coarse grained quartz-rich leucogranite defined as a major subunit of the Trans-Labrador batholith (Kerr, *this volume)*. Similar highs are also associated with granitic units to the southwest. In the Benedict Mountains area, there is a suggestion of a fairly extensive high, but there is no data available for the rugged area along the coastal strip.

The remaining major anomaly for this factor lies within the Archean terrane northeast of Snegamook Lake. This area is underlain mostly by Archean granitoid rocks that are dominated by tonalites and granodiorites, which do not usually display enrichment in these elements. It is, however, close to granitoid units associated with the Harp Lake Complex (Emslie,1980).

Factor 2 [pH, Ni, -F(H_2O), -U(H_2O), As]

Factor 2 shows strong positive loadings for pH and Ni, with a moderate negative loading for U(H_2O) and a weak negative loading for U(H_2O). Arsenic also has a small positive loading. This association suggests that it may reflect the opposite of factor 1, i.e., the influence of more basic or less evolved rock types containing more CaO and MgO (hence less acidic lake water) and Ni, but lower levels of U and F.

The most obvious feature of the factor 2 score distribution is that the Archean block, Moran Lake Group and parts of the Bruce River Group display moderate to strong enrichment, whereas all other units are low and generally below the 60th percentile. The most prominent highs appear to be associated with mafic volcanic units (not shown on Figure 2) in the Moran Lake Group and the Archean. However, areas within the Archean block that are underlain mostly by quartzofeldspathic gneisses still display moderate enrichment, as does a large early Proterozoic granitoid body that intrudes the Archean in the east. In contrast, granitoid rocks within the Trans-Labrador batholith are characterized by Factor 2 values below the 60th percentile, which is almost the exact inverse of the factor 1 pattern. This could have a number of explanations; it could reflect differences in crustal level, and perhaps even a contrast in source materials for these two areas of granitoid rocks and gneisses.

The edge of the exposed Archean block does not correspond exactly with that of the factor 2 high. This may reflect southward glacial transport from the Archean, but it might also reflect the influence of unseen Archean basement on the geochemical signatures of magmatic rocks derived from it, or acquired by passing through it.

Factor 3 [rF, Pb, F(H_2O), rZn]

Factor 3 is a rather peculiar association that shows strong positive loadings for rF and Pb, with lesser loadings for rZn and F(H_2O). The significance of such an association is uncertain, but it may be a reflection of alkaline or peralkaline

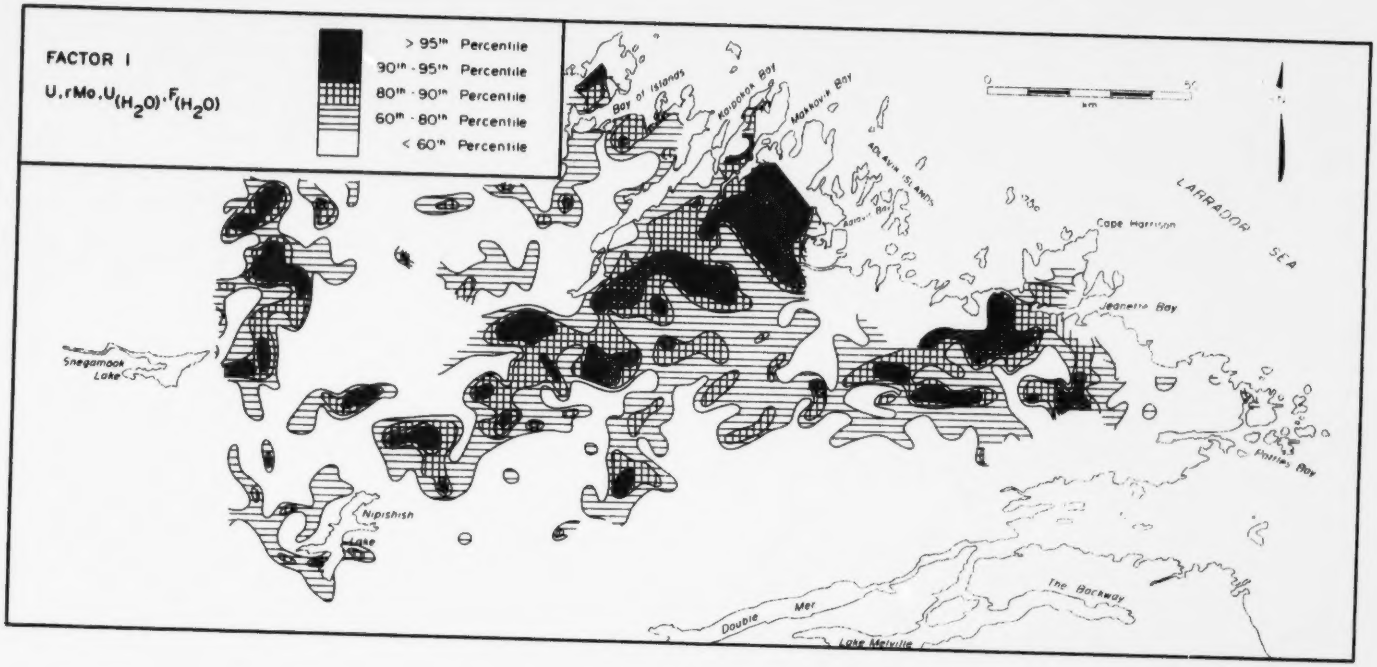
FACTOR I
U.rMo.$U_{(H_2O)}$.$F_{(H_2O)}$
> 95th Percentile
90th - 95th Percentile
80th - 90th Percentile
60th - 80th Percentile
< 60th Percentile
0
50
km
LABRADOR SEA
Bay of Islands
Kaipokok Bay
Makkovik Bay
ADLAVIK ISLANDS
Adlavik Bay
Cape Harrison
Jeanette Bay
Pottles Bay
Snegamook Lake
Nipishish Lake
The Backway
Double Mer
Lake Melville

Figure 3: *Factor 1 score distribution map.*

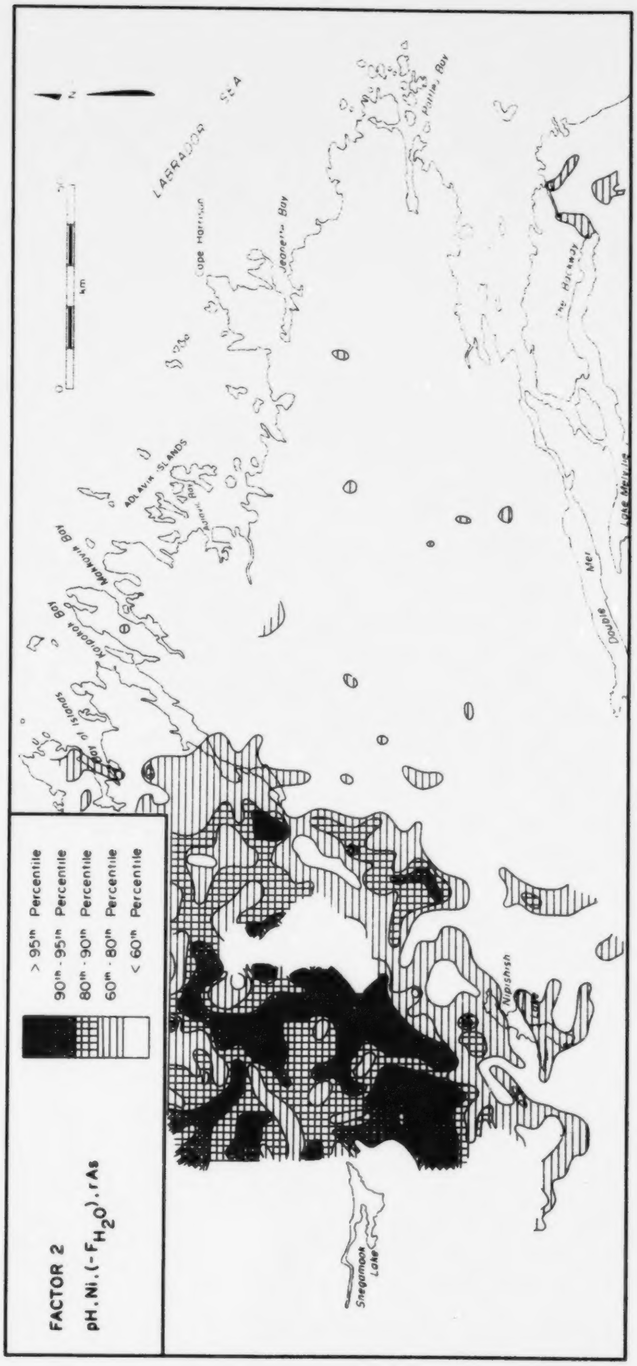
FACTOR 2
pH.Ni.(-F$_{H_2O}$).rAs
> 95th Percentile
90th - 95th Percentile
80th - 90th Percentile
60th - 80th Percentile
< 60th Percentile
0
km
N
LABRADOR SEA
Cape Harrison
Jeanette Bay
ADLAVIK ISLANDS
Makkovik Bay
Kaipokok Bay
Bay of Islands
Snegamook Lake
Nipishish Lake
The Backway
Double Mer
Lake Melville

Figure 4: *Factor 2 score distribution map.*

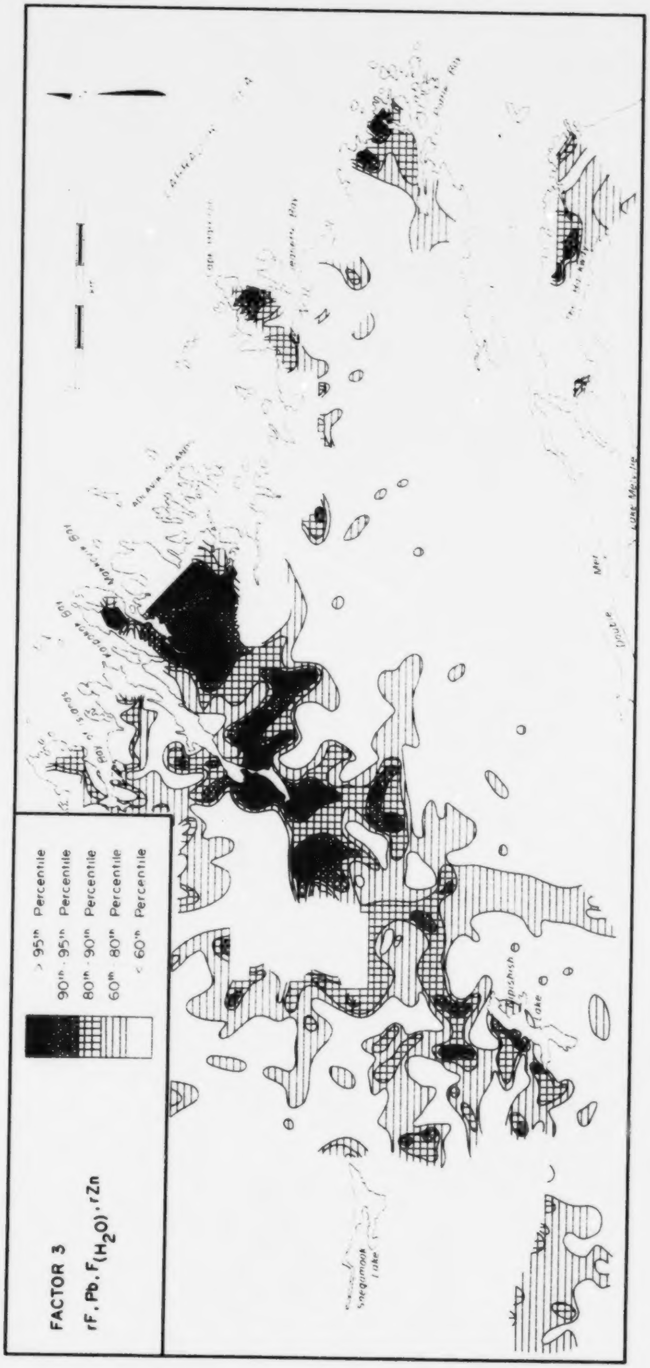
FACTOR 3
rF, Pb, F(H2O), rZn
> 95th Percentile
90th - 95th Percentile
80th - 90th Percentile
60th - 80th Percentile
< 60th Percentile
Snegamook Lake
Pipishish Lake
Double Mer
Lake Melville

Figure 5: *Factor 3 score distribution map.*

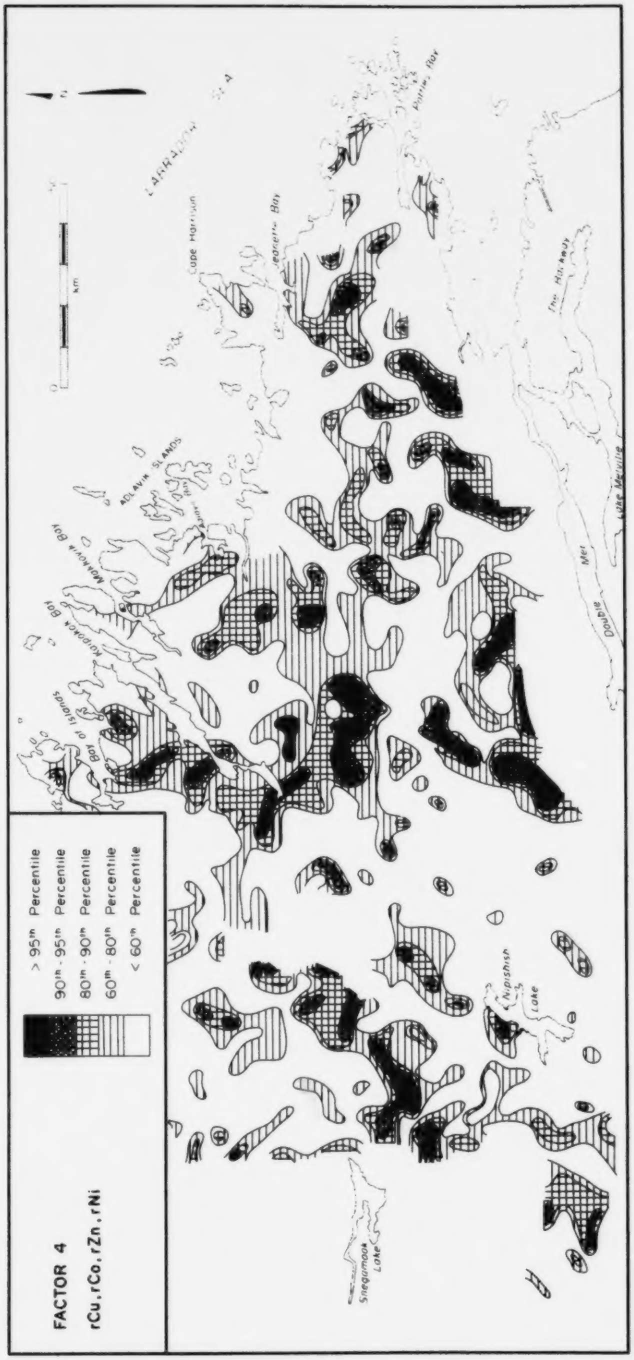
FACTOR 4
rCu, rCo, rZn, rNi
▆ > 95th Percentile
▩ 90th - 95th Percentile
▦ 80th - 90th Percentile
▥ 60th - 80th Percentile
□ < 60th Percentile
km
N
LABRADOR SEA
Cape Harrison
Jeanette Bay
Pottles Bay
The Backway
Lake Melville
Double Mer
ADLAVIK ISLANDS
Makkovik Bay
Kaipokok Bay
Bay of Islands
Nipishish Lake
Snegamook Lake

Figure 6: *Factor 4 score distribution map.*

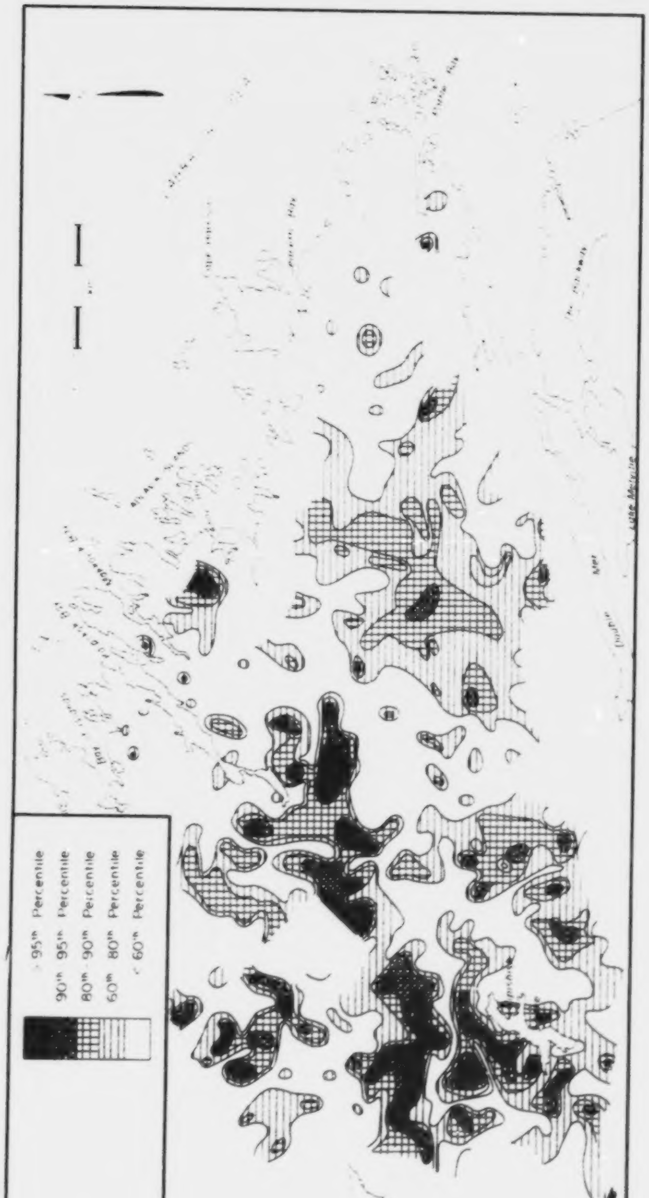
FACTOR 5
rAg.rAs
> 95th Percentile
90th-95th Percentile
80th-90th Percentile
60th-80th Percentile
< 60th Percentile
Snegamook Lake
Lake Melville

Figure 7: Factor 5 score distribution map.

magmatism. It resembles in many respects the signature of the Flowers River igneous suite in northern Labrador (McConnell, 1982,1984), but does not seem to be associated with high Mo. However, some areas high in factor 3 are also high in factor 1, which has a high loading for Mo (Table 2). The Pb-F-Zn association is associated with mineralized granitoid plutons in insular Newfoundland (Davenport, 1982b), and may reflect alteration processes related to epigenetic mineralization.

Factor 3 scores do not show a clear correspondance with any one geological unit, but the unit most commonly underlying anomalous areas is the upper Aillik Group, in particular the more northerly outcrop area. However, this area also contains a number of small granitoid plutons (as discussed above) and it is thus difficult to evaluate the precise bedrock unit responsible. If this signature does indeed represent the upper Aillik Group, it is certainly not shared by the more southerly outcrop area of this unit, which is generally low in factor 3.

The most prominent highs lie south of Makkovik in the same general area as the main factor 1 high. However, in detail it can be seen that the most anomalous areas flank the factor 1 high. Anomaly trends are once again northwest, almost at right angles to the dominant structural grain of the area. Similar trends are apparent in a complex anomaly pattern near the southern end of Kaipokok Bay. This is again slightly displaced from a similarly large but somewhat weaker factor 1 anomaly coinciding with a granitoid unit in the Trans-Labrador batholith. The presence of several smaller anomalous areas within the batholith suggests that this may also be a granitoid-related signature, rather than a signature related directly to the upper Aillik Group. The generally coincident, but slightly displaced positions of factor 1 and 3 highs may be indicative of a zoning effect similar to that noted by Davenport (1982b) around some mineralized granitoid bodies in southern Newfoundland.

Factor 4 [rCu, rCo, rZn, Ni]

Factor 4 is a base-metal association that shows high positive loadings for rCu, rCo and rZn, with a smaller loading for Ni. Interpretation of this association is difficult. The presence of Ni could indicate a correlation with igneous rocks of more mafic composition, which are commonly enriched in these elements, but the association might also reflect the presence of base metal mineralization. The factor 4 pattern is rather disorganized in general appearance, but some of the larger anomalies show a fairly good general correspondance with geologic units.

A series of linked highs in the west correspond generally with the outcrop area of the Moran Lake Group, which is known to contain minor base-metal mineralization (Ryan, 1984). A second prominent high corresponds with the Trans-Labrador batholith and the upper Aillik Group in the centre of the area, and is associated with the factor 1 and 3 highs discussed above. The large factor 1 high near Makkovik is not represented by an anomaly.

The most extensive anomalous areas form a confusing pattern in the Grenville Province south of the southern limit of the Trans-Labrador batholith. This area is underlain mostly by high-grade gneisses that are cut by minor gabbroic intrusions termed the Michael Gabbros. The highs might be related to the gabbro bodies, but might also correlate with regional paragneiss units mapped in this area by Gower (1984). The rather diffuse anomaly pattern and the location of these highs near the edge of the study area makes precise interpretation difficult.

A number of moderate highs in the Kaipokok Bay - Makkovik Bay areas show northwest-trends reminiscent of those shown in this area by factors 1 and 2.

Factor 5 [rAg, rAs]

Factor 5 shows a strong positive loading for rAg and a moderate positive loading for rAs. Both Ag and As are widely considered to be good indicators for Au mineralization. It is tentatively suggested that factor 5 may reflect the potential of various units for Au and Ag mineralization.

The score distribution pattern for factor 5 shows a very good correlation with the supracrustal sequences of the Bruce River Group and the southern outcrop area of the upper Aillik Group. The Moran Lake Group is generally low, as is much of the northern outcrop area of the upper Aillik Group, with the exception of a high south of Makkovik, which is generally coincident with a showing containing Ag (Wilton *et al.*, *in preparation)*. It should be noted, however, that the areas adjacent to Au-Ag showings northeast of Makkovik (Wardle and Wilton, 1984) are not covered by lake sediment samples, and this high could be considerably larger than that shown on the map.

Remaining factor 5 highs appear to correlate mostly with Archean metavolcanic units, which could also have potential for Au-Ag mineralization. However, there is a noticeable absence of response over the mafic volcanic rocks of the Moran Lake Group, which would appear to suggest that factor 5 represents more than a general response to volcanic sequences.

SUMMARY AND CONCLUSIONS

The statistical analysis techniques discussed in this report appear to have been effective tools in both reducing the volume of data under consideration and highlighting regional geochemical patterns within the eastern Central Mineral Belt. The factor score maps in Figures 3 to 7 show much smoother patterns than the 15 raw element maps that they replace, and also appear to show a clearer relationship to bedrock geological patterns. For some areas the correspondance is very striking indeed; as in the case of the factor 2 distribution over the Archean or the factor 5 distribution over the Bruce River Group. The results discussed in this report are necessarily preliminary, and more exhaustive examination of data is required to both substantiate and improve the interpretation of these results. Nevertheless, a number of inferences can be drawn from the patterns discussed in the preceding section:

1. The exposed Archean block has a very characteristic geochemical signature, illustrated mostly by the factor 2 distribution, which is attributed to a generally

higher Ni content and more intermediate quartzofeldspathic components compared to adjacent Proterozoic terranes. The depletion in U and F suggested by the loadings for factor 2 may perhaps be related to expulsion of such elements during repeated high-grade metamorphism. This signature is shared by a large Proterozoic granitoid body that intrudes the Archean block, but is lacking completely from the younger granitoids of the Trans-Labrador batholith.

2. Parts of the Trans-Labrador batholith, and particularly its northern margin, show geochemical signatures that suggest the presence of evolved granitoid rocks, which may have some potential for granophile mineralization (shown by factor 1 and factor 3 distributions). The area along the northern margin of the batholith is marked by a number of smaller granitoid plutons whose roof zones are cut by the erosion surface. If factor 3 also represents a granitoid association, there may well be multi-element zoning patterns in some areas of the type recognized by Davenport (1982b) in Newfoundland granites.

3. The supracrustal sequence of the Moran Lake Group is enriched in a base-metal association (factor 4) relative to the other supracrustal sequences, which may suggest that this package as a whole has some potential for base metal deposits (perhaps sediment hosted). This is in accordance with the presence of several minor Pb-Zn-Cu occurrences (Ryan, 1984). It is also possible that large diffuse anomalies in poorly exposed regions of the Grenville Province may be associated with paragneiss units, suggesting perhaps that these areas might be of some interest.

4. Ag and As appear to be associated together and both show high positive loadings on factor 5, which is generally anomalous in areas underlain by the Bruce River Group and also in the southern outcrop area of the upper Aillik Group. Both these areas contain felsic volcanic sequences, which might have potential for epithermal gold mineralization. Although recently recognized Au mineralization northeast of Makkovik is not covered by lake sediment data, an area south of Makkovik known to host silver-bearing showings is enriched in factor 5.

5. Although the signature of the northern outcrop area of the upper Aillik Group is difficult to assess due to the presence of late granitoid rocks, the patterns for factor 3 and factor 5 may indicate that it differs somewhat from the southern area. This could represent a difference in tectonic setting or perhaps even an age difference. The factor 5 pattern may also suggest a geochemical affinity between the southern area and the adjacent Bruce River Group.

In general, the results of this analysis suggest that, in addition to a well established potential for uranium mineralization, the Central Mineral Belt might also hold some promise for sediment-hosted base-metal deposits, epithermal precious-metal mineralization and granite-hosted Mo, Cu, Sn, W, Nb, Ta and a range of other lithophile elements.

Possible avenues along which this investigation could be expanded include the enlargement of the data set to include other geological subdivisions within the Central Mineral Belt, in particular the Seal Lake Group and Letitia Lake area, both of which host types of mineralization not recognized in the current study area. An examination of patterns over these areas might aid in interpretation of the factor patterns discussed in this report. Curvilinear regression models might offer an improvement on the linear models used here. A third possibility is to move from examination of single element variables to basing the entire analysis on elemental ratios. Geochemical dispersion patterns related to mineralizing events are commonly multi-element, and it may be worthwhile to adopt an *additive* approach, where areas enriched in 2 or more factors are accorded the highest priority.

In conclusion, it apperas that a logical step in regional geological studies in this province should be toward presentation of regional geochemical data in a reduced and processed form. It is hoped that this preliminary account will illustrate the potential of such a step, and perhaps also prompt some discussion of the suitability and usefulness of these and other methods.

ACKNOWLEDGEMENTS

This report has benefited greatly from discussions with a number of persons interested in geochemistry, data processing and Labrador geology. In particular, we wish to thank A.B.Ryan, R.J.Wardle and J.McConnell for reviewing the manuscript, and also D.J.Furey of Memorial University for providing a thorough review of our interpretation of statistical data. Gerry Squires is thanked for his patience in contouring numerous maps, and Lyne Houle for adding the finishing touches by coloring them.

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VLF-EM INVESTIGATIONS IN INSULAR NEWFOUNDLAND

Joan Tod
Geochemistry and Geophysics Section

ABSTRACT

Two projects were initiated to investigate the use of VLF-EM as a mapping tool. The first was aimed at tracing out a drift-covered contact between the Table Head and Codroy groups on the Port au Port Peninsula. Unique in its electromagnetic signature, the contact was mappable in those areas traversed by ground work. The second project was located in the Badger area. A ground survey was undertaken to evaluate the interpretive utility of airborne VLF-EM data. It was found that conductive units, such as the Caradocian graphitic shale unit, are traceable with airborne VLF-EM.

PORT AU PORT PENINSULA, NEWFOUNDLAND

Introduction

Celestite-barite deposits are found at the contact between the Carboniferous Codroy Group and the Ordovician Table Head Group on the Port au Port Peninsula, western Newfoundland. Pb-Zn mineralization is also known to occur within this suite of rocks (Howse, 1984). A thick cover of drift blankets the area and has prevented accurate mapping of the location of the contact between the two groups.

Geochemical investigations (Davenport, *et al.*, 1975) of the stream sediments on the Port au Port Peninsula yielded anomalous values along the projected length of the contact. Therefore it was decided to test the ability of geophysical techniques in determining the contact location.

General Geology

An eroded highland runs along the southern margin of the central part of the Port au Port Peninsula (Figure 1). This escarpment consists of the Ordovician Table Head Group which strikes east-west and dips approximately 17 degrees to the north. Carboniferous rocks (limestone, shale, sandstone) of the Codroy Group onlap the Ordovician strata to the north, and form a drift-covered lowland. The area to the north (mainly Shoal Point) is underlain by Hadrynian to Middle Ordovician sedimentary rocks of the allochthonous Humber Arm Supergroup (Schillereff and Williams, 1979).

The Ordovician limestones are interpreted as having karst features prior to deposition of the Carboniferous sediments. This Carboniferous infilling outlines the topography of the Ordovician surface, which appears to be dominated by 'north trending, steep-sided, fault-controlled ... paleokarst valleys' (Knight, 1983).

Barite and celestite mineralization has been found at the contact between limestone units of the Table Head and Codroy groups in the study area. It apparently occurs as both a replacement deposit of calcareous beds (Johnson, 1954) and as space filling of cavities (Knight, 1983). Known mineral deposits (such as the Ronan) are lens shaped and concordant with the enclosing strata.

Field Work

During June, 1985, twelve north-south traverses were positioned over the projected contact location south of Shoal Point. Limited access confined these traverses to old cut lines and stream beds. VLF-EM (very low frequency - electromagnetic) measurements were taken with a Geonics EM-16 instrument. Data were recorded at 25 m intervals. Magnetic data (using a Scintrex MP-2) were also recorded over a small portion of the survey; little anomalous variation was noted in these records.

Time limitations prevented extensive line cutting and therefore a consistent line bearing was not always possible to maintain. Where vegetation or topography caused slight changes in line direction, the appropriate bearings were recorded from station to station. The collected data were later mathematically projected onto a straight line, which was determined by a method of least squares. Equidistant stations were then interpolated from the projected readings. A Fraser filter was applied to these values and depth sections of equivalent current sources were generated (Karous and Hjelt, 1983).

Figure 2 shows the investigated contact, as well as the orientation of the projected traverses. Three representative profiles of the VLF-EM data plus the calculated depth sections are shown in Figure 3.

Discussion of Results

The primary aim of this investigation was to determine if VLF-EM is capable of discerning the contact between the Table Head and Codroy groups. It was also important to see if this type of survey could distinguish between the geophysical signature of the contact and that of other geological features.

This project is a contribution to the Canada-Newfoundland Mineral Development Agreement, 1984-1989

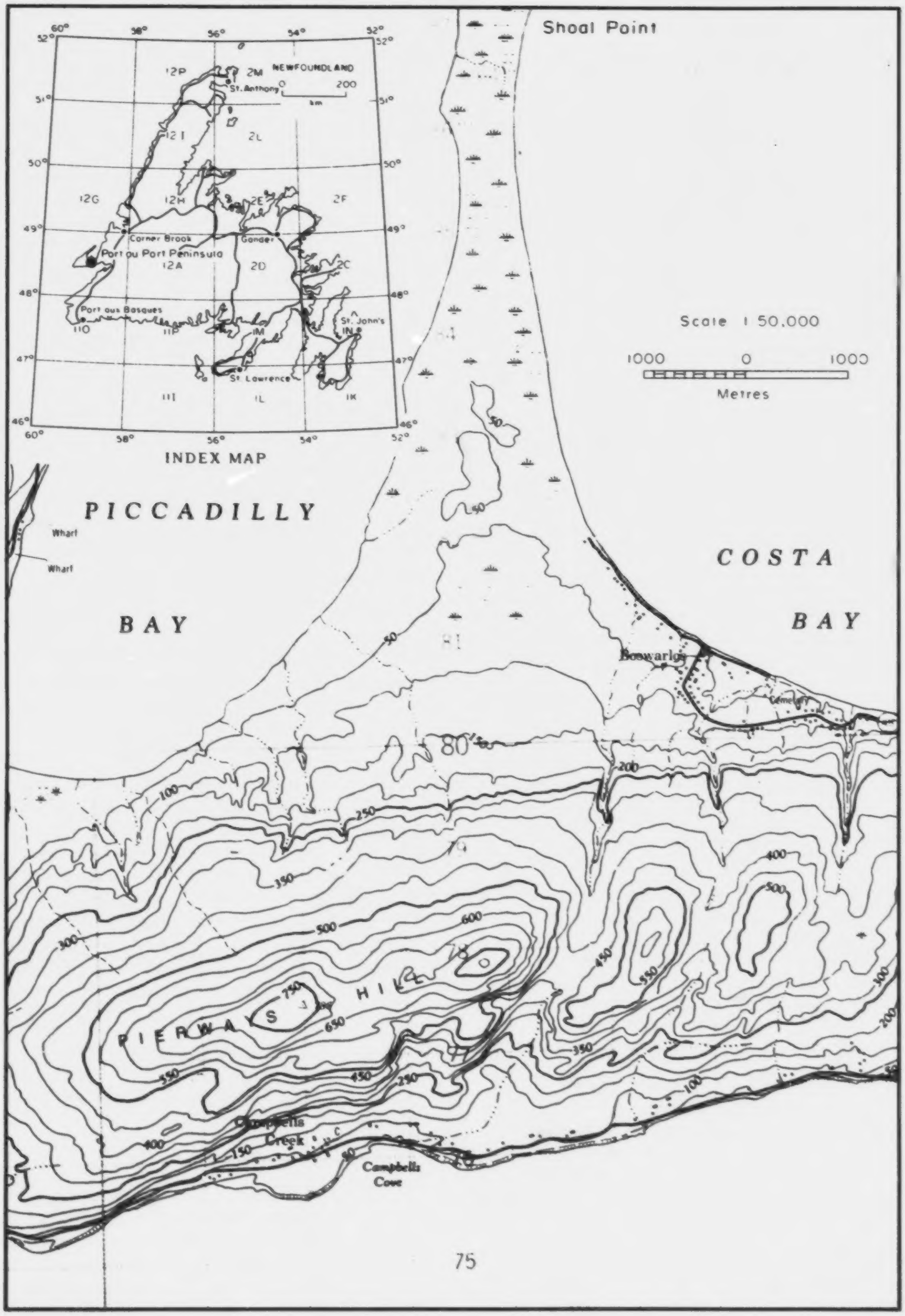
Shoal Point
INDEX MAP
NEWFOUNDLAND
St. Anthony
Corner Brook
Gander
Port au Port Peninsula
Port aux Basques
St. John's
St. Lawrence
12P
2M
12I
2L
12G
12H
2E
2F
12A
2D
2C
11O
11P
1M
1N
11I
1L
1K
0
200
km
60°
58°
56°
54°
52°
46°
47°
48°
49°
50°
51°
Scale 1:50,000
1000
0
1000
Metres
PICCADILLY
BAY
Wharf
Wharf
COSTA
BAY
Boswarlos
Cemetery
PIERWAYS HILL
Campbells Creek
Campbells Cove
50
100
150
200
250
300
350
400
450
500
550
600
650
750
75
80

Figure 1: *Location map showing topography.*

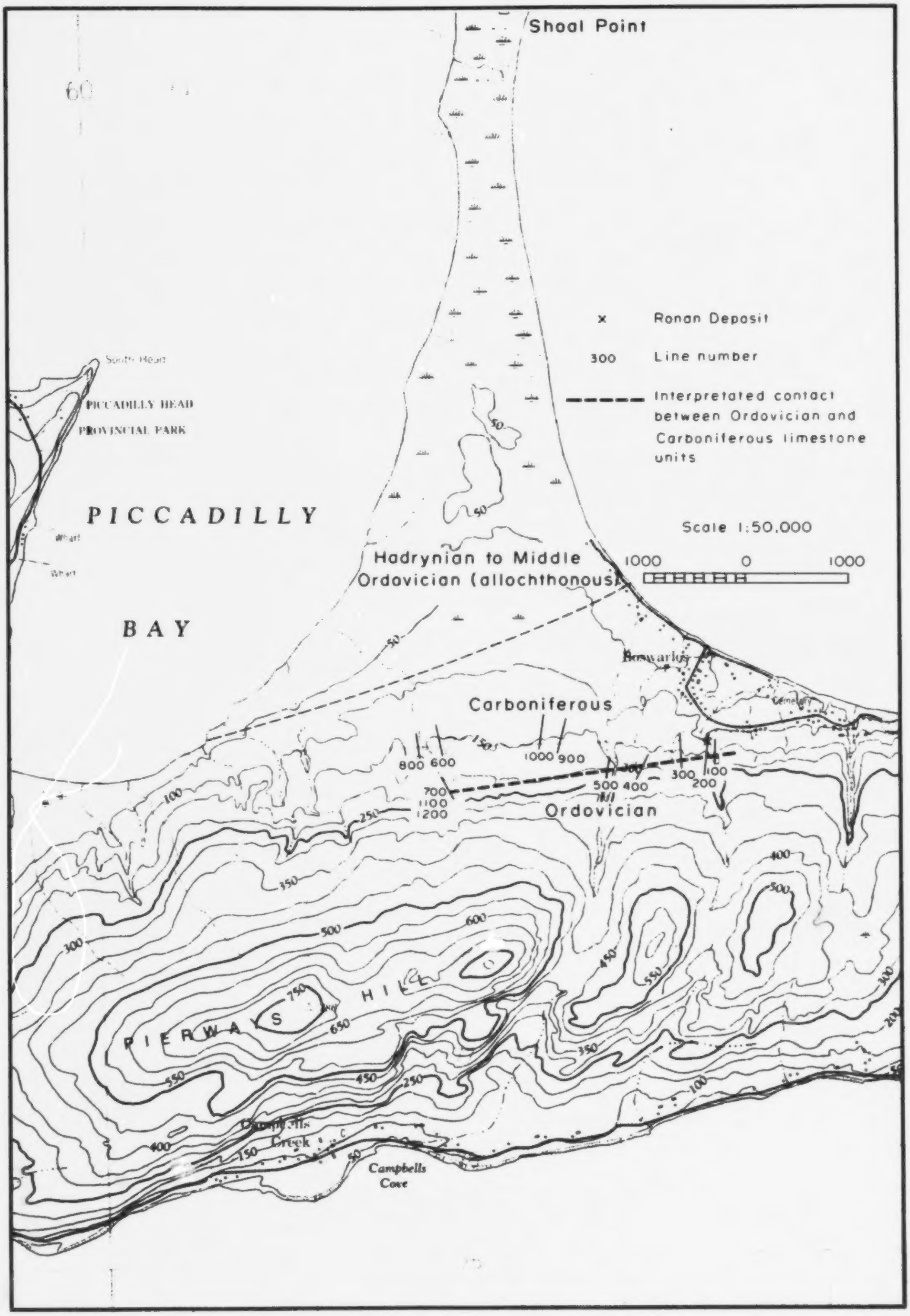
Shoal Point
60
South Head
PICCADILLY HEAD
PROVINCIAL PARK
PICCADILLY
BAY
Wharf
Wharf
× Ronan Deposit
300 Line number
Interpretated contact between Ordovician and Carboniferous limestone units
Scale 1:50,000
1000 0 1000
Hadrynian to Middle Ordovician (allochthonous)
Boswarlos
Cemetery
Carboniferous
Ordovician
800 600
1000 900
700
1100
1200
500 400
300 100
200
PIERWAYS HILL
Campbells Creek
Campbells Cove
50
100
150
250
350
400
450
500
550
600
650
750
300
200

Figure 2: *Orientation and location of traverses.*

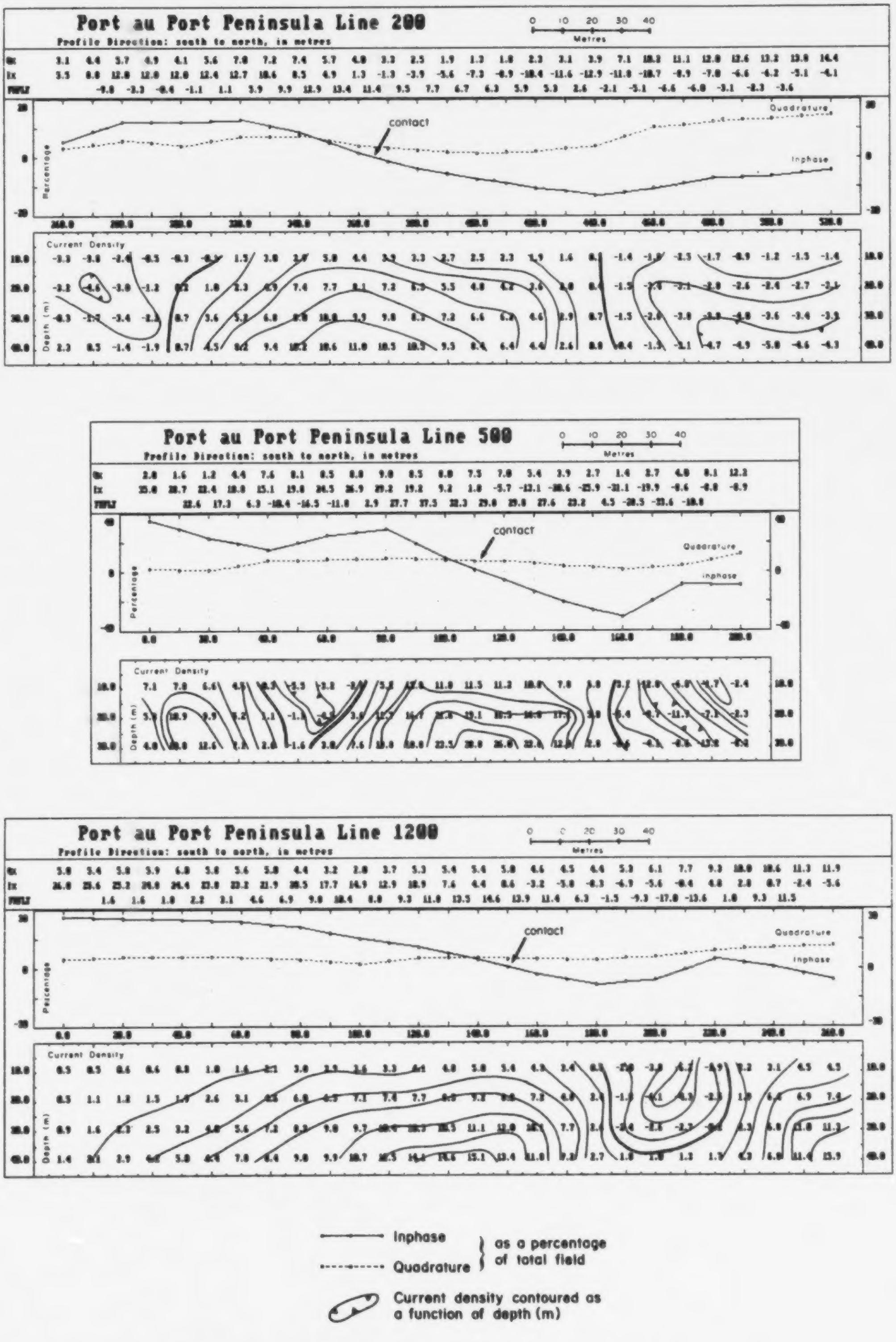

Figure 3: *VLF-EM profiles and depth sections of Lines 200, 500 and 1200.*

There is no doubt that the contact, although drift covered, is traceable using standard VLF-EM geophysical equipment. It was readily identifiable on 8 of the 12 traverses and is illustrated in Figure 3. Lines 600, 800, 900 and 1000 were positioned to the north of the target area and all four produced very flat response profiles. This supports the interpretation that the anomalies in the target area reflect the contact between the two groups.

Line 200 crosses the Ronan deposit. This barite/celestite occurrence has been thoroughly investigated by surface mapping and drilling programs, and its approximate size and location are well known. Barite and/or celestite are unlikely candidates for causing an electromagnetic anomaly as they do not have the necessary conductivity characteristics. Since there is nothing to indicate significant Pb-Zn mineralization at this locality, the VLF-EM anomaly on Line 200 would appear to be a representative contact signature.

Conclusion

An examination of the data indicates that there is very little difference in anomaly characteristics from line to line. Line 200 is a typical example of the electromagnetic response found on all the profiles. This implies that there are no positive indications of Pb-Zn mineralization; at the same time, it does not provide any information regarding celestite/barite occurrences. If two or more traverses were run over the known Pb-Zn deposits, it would provide some parameters on the magnitude of response for such mineralization. Lead Cove and Bellmans Cove are suitable sites for such a test.

The interpreted location of the contact also has a topographical expression in the area. The contact appears to follow the northern edge of a low rise that lies just to the north of, and parallel to, the hills along the south shore of the Port au Port Peninsula.

BADGER AREA

Introduction

A graphitic shale and chert unit of Caradocian age transects the central portion of the Badger (12A/16) map area (Figure 4). It delineates much of the regional folding and faulting patterns of this area, and divides the area into two major geological subdivisions. The distribution of this unit is defined by exposures of graptolite-bearing shales and a regional airborne electromagnetic survey (Kean and Jayasinghe, 1982). However, recently acquired airborne geophysical data (Geological Survey of Canada gradiometer and VLF-EM survey, 1983) suggest modifications to the assumed map pattern of the shale/chert unit.

The graphite content of the shale produces an electromagnetic anomaly that is easily detected by VLF-EM equipment. It is this characteristic which facilitated the interpretation of the airborne data (Scott, 1985) and prompted the ground followup. The magnitude of the anomalous response is proportional to graphite concentration, and depends on the acuteness of the angle between traverse orientations and strike direction. The purpose of the ground geophysical work was to assess the effectiveness of the airborne VLF-EM data as a mapping tool in this area.

General Geology

Clastic sedimentary rocks and minor intercalcated volcanic rocks underlie the middle part of the Badger map area. An extensive unit of black shale and chert containing Caradocian graptolites separates the Middle Ordovician and older Victoria Lake Group to the south from a Late Ordovician to Silurian clastic sedimentary sequence to the north. The Victoria Lake Group consists of interbedded greywacke, shale, siltstone and conglomerate with minor volcanic rocks. The overlying sedimentary rocks are typical of central Newfoundland post-Taconic greywacke and conglomerate sequences. Deformation of these rocks includes folding along northeast-trending axes and faulting along northwest- and northeast-trending faults.

Field Work

Two different areas (#1 and #2) were covered by 9 traverses. The first area lies to the south of Buchans Junction, between Highway 370 and the Exploits River (Figure 5). The airborne VLF-EM coverage indicates a well-defined anomaly to the southeast of the assumed location of the shale unit. The second area is accessible from Grand Falls and is located south of the junction between Highway 370 and Highway 98, which runs north-northwest to Millertown Junction (Figure 6). The map position of the shale unit was originally interpreted from a 1966 INPUT (Induced Pulse Transient) survey by McIntyre Porcupine Mines Ltd. The more recent Geological Survey of Canada VLF-EM data suggest two narrower units instead of the single, wider one (Scott, 1985), but the signature is not sufficiently anomalous to confirm this interpretation.

VLF-EM readings were recorded every 25 m using a Geonics EM-16 meter. As well, approximately half of the lines have magnetic coverage (using a Scintrex MP-2). Positioning of the traverses was constrained by the location of a major power line, which runs east-west through the map area. Ten rock samples were taken.

Discussion of Results

Figures 7 and 8 show the electromagnetic profiles of the traverses from both study areas. A Fraser filter was applied to the recorded values, after which depth sections of equivalent current sources were generated. These plots show four quantities: inphase response, quadrature response, Fraser filter values as a percentage of the total field, and current density as a function of depth. In general, well-defined crossovers (or changes in polarity) in the inphase readings indicate a significant change in conductivity. A summary of each traverse is given in Table 1 and interpreted locations of the shale unit are shown on each of the profiles, where applicable. Area #2 had a number of rock outcrops; identification of the collected samples is given in Table 2 (see also Figure 8).

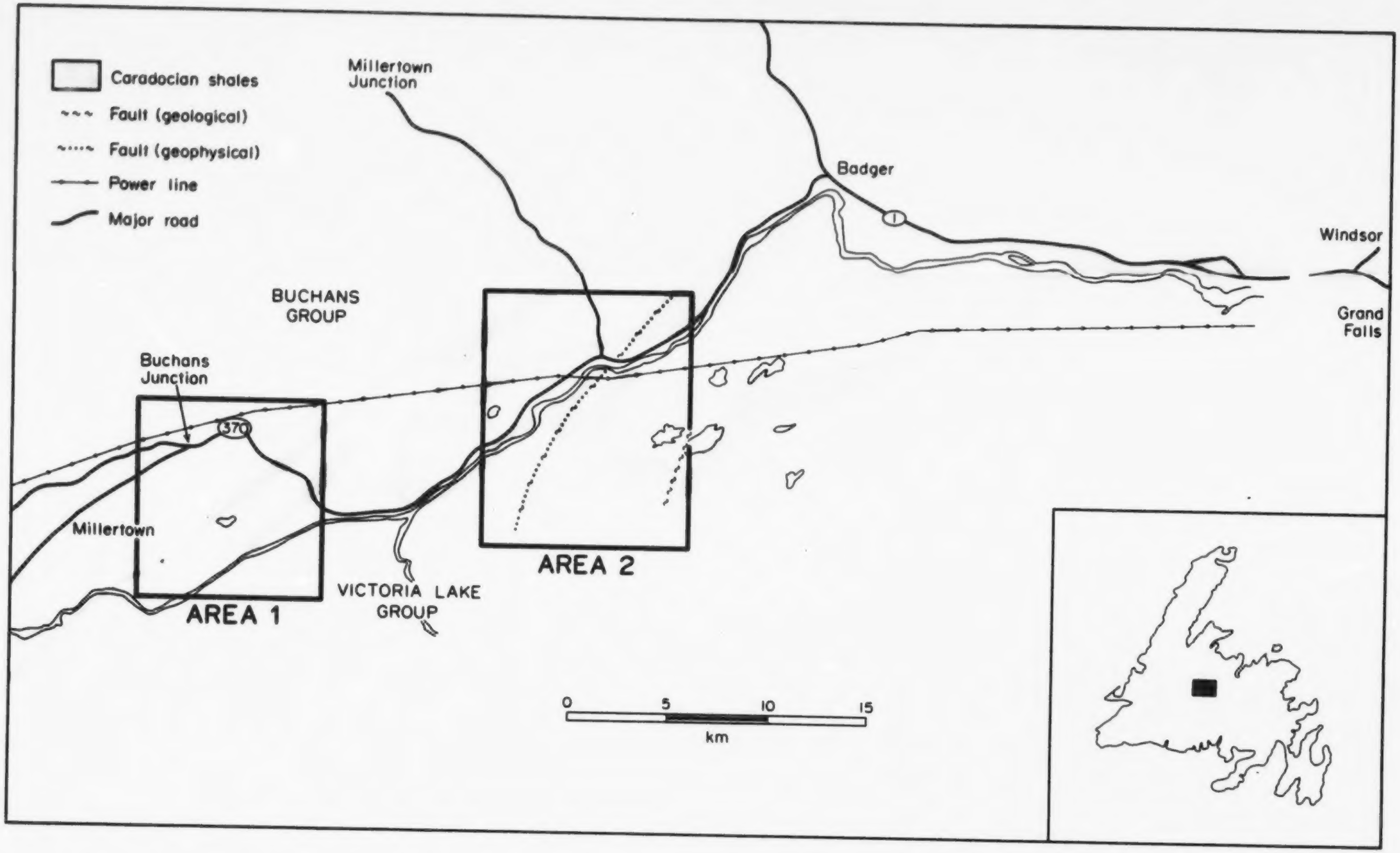
Caradocian shales
Fault (geological)
Fault (geophysical)
Power line
Major road
Millertown Junction
Badger
1
Windsor
Grand Falls
BUCHANS GROUP
Buchans Junction
370
Millertown
AREA 1
AREA 2
VICTORIA LAKE GROUP
0
5
10
15
km

Figure 4: *Distribution of the Caradocian shale unit in the Badger map area (after Kean, 1977) and location of VLF-EM study areas.*

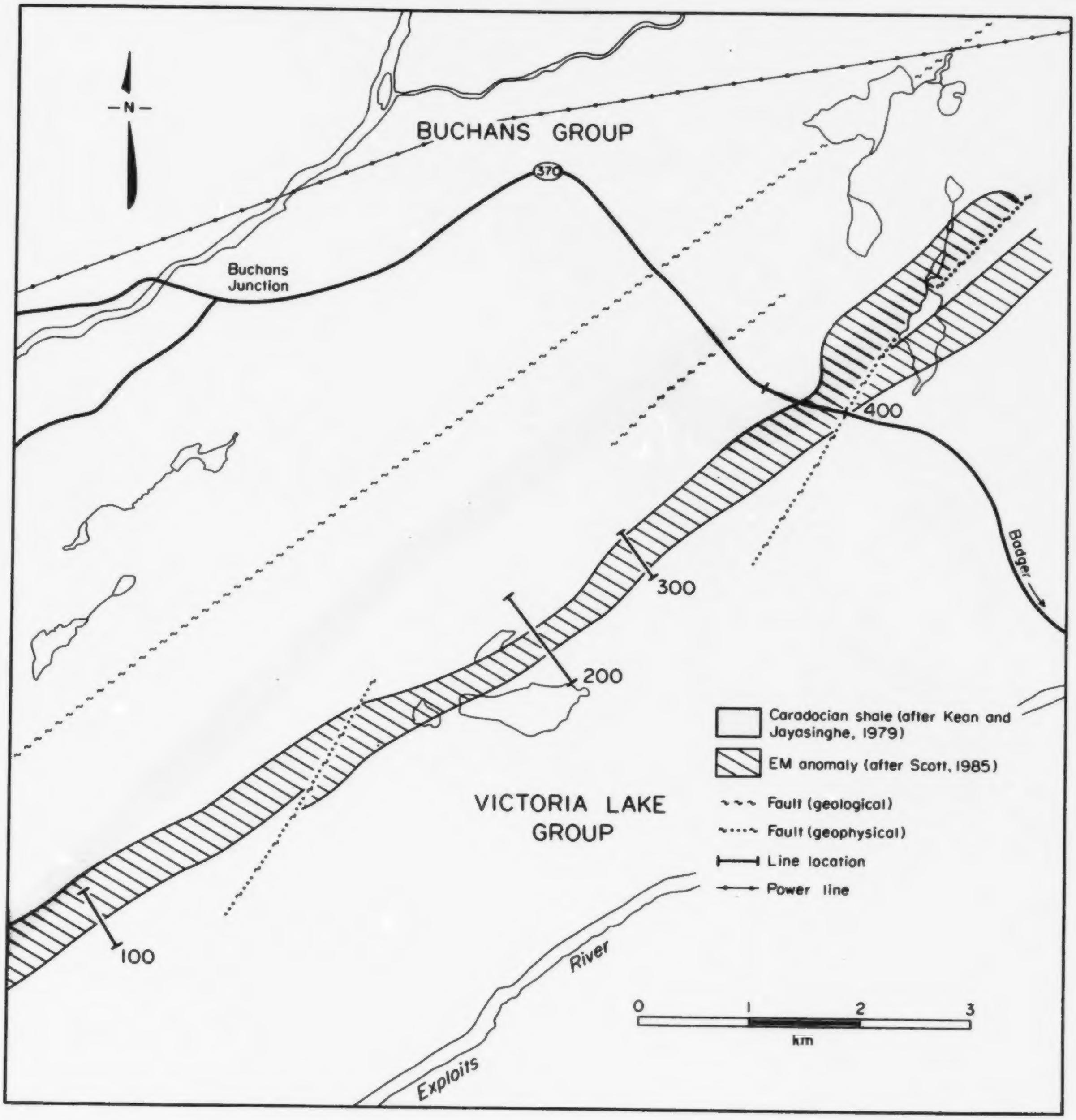
N
BUCHANS GROUP
370
Buchans Junction
400
300
200
100
Badger
VICTORIA LAKE GROUP
Caradocian shale (after Kean and Jayasinghe, 1979)
EM anomaly (after Scott, 1985)
Fault (geological)
Fault (geophysical)
Line location
Power line
0
1
2
3
km
Exploits River

Figure 5: *Location of EM anomaly relative to mapped shale unit, showing position of ground traverses for Area #1.*

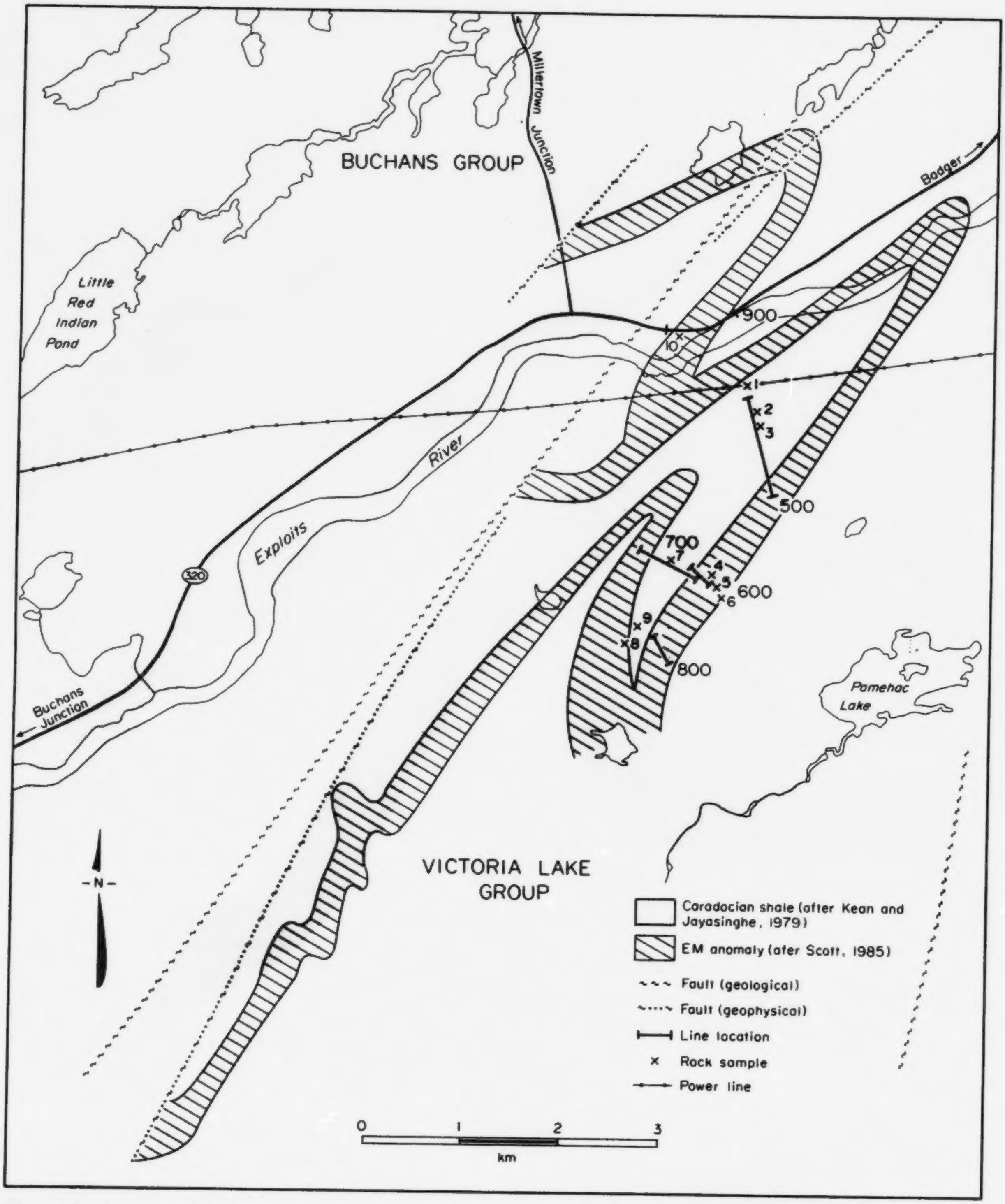
BUCHANS GROUP
Millertown Junction
Little Red Indian Pond
Badger
900
10
1
2
3
500
700
7
4
5
6
600
9
8
800
Exploits River
320
Buchans Junction
Pamehac Lake
VICTORIA LAKE GROUP
N
Caradocian shale (after Kean and Jayasinghe, 1979)
EM anomaly (afer Scott, 1985)
Fault (geological)
Fault (geophysical)
Line location
Rock sample
Power line
0
1
2
3
km

Figure 6: *Location of EM anomaly relative to mapped shale unit, showing position of ground traverses for Area #2.*

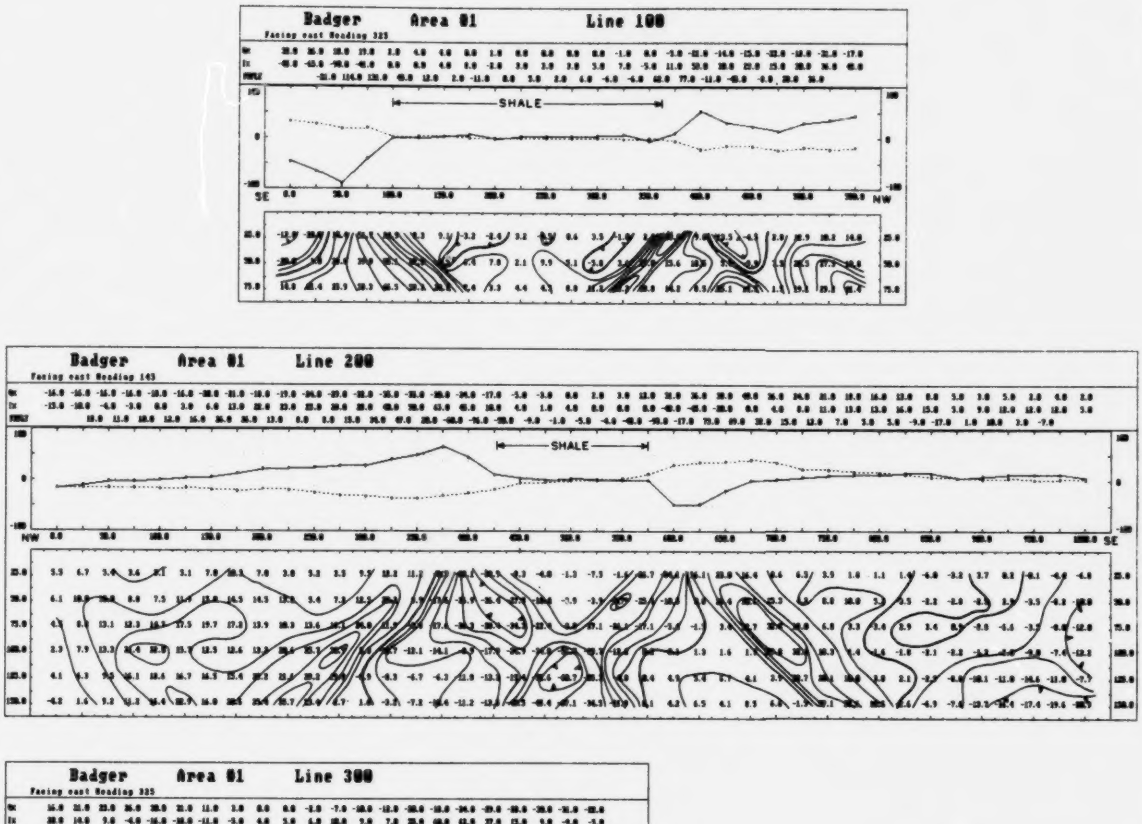

Figure 7: *Profiles of VLF-EM traverses for Area #1.*

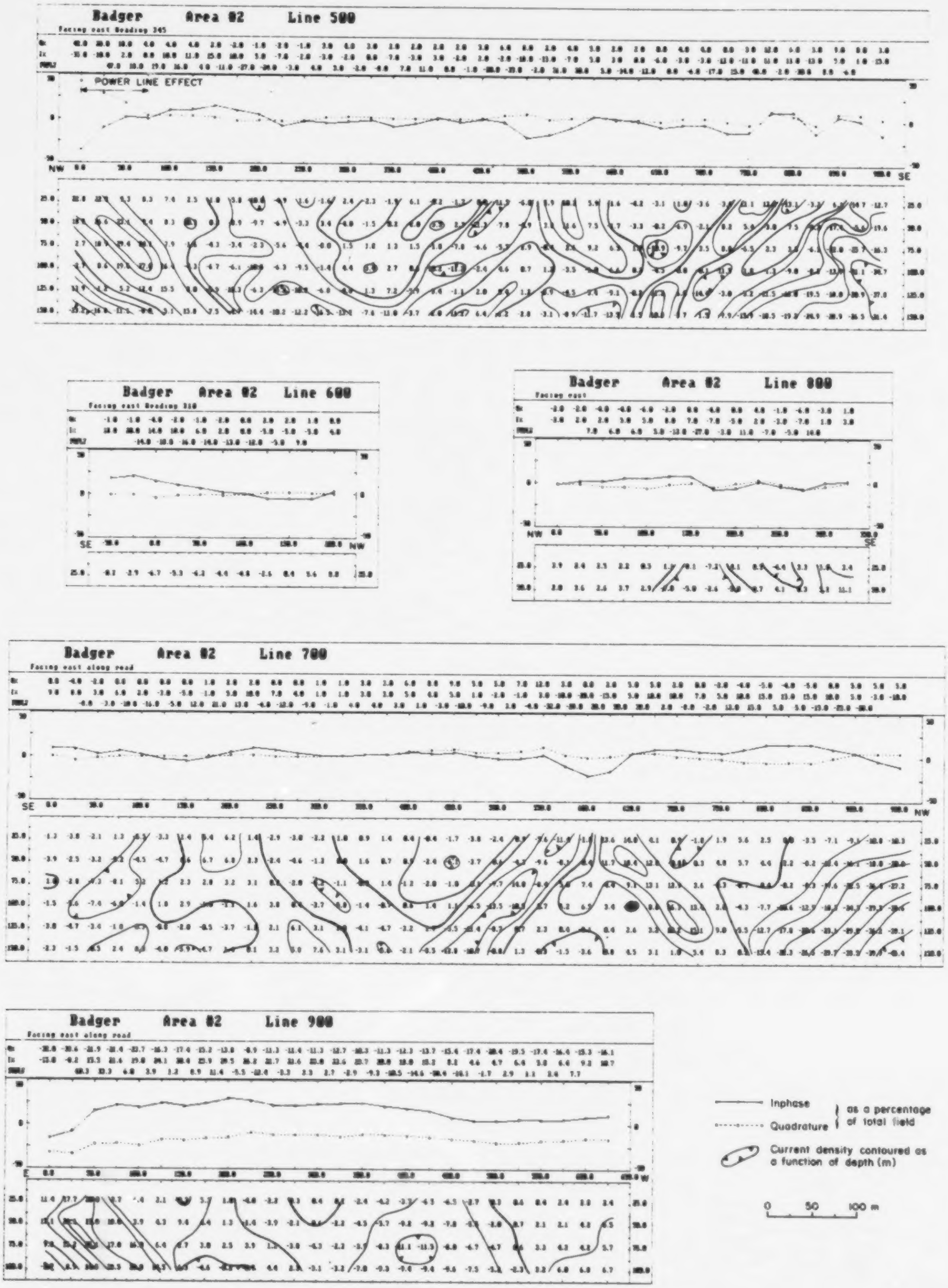

Figure 8: *Profiles of VLF-EM traverses for Area #2.*

Table 1. Summary of Traverses

Area #1

Line	Direction	Response
100	SE to NW	Graphitic shale unit between Stations 100 and 350.
200	NW to SE	Graphitic shale unit between Stations 425 and 575.
300	SE to NW	Graphitic shale unit between Stations 175 to 325.
400	WNW to ESE	Northwest edge of graphitic shale unit at Station 250; second anomaly of unknown source, centered about Station 425, masks southeast edge of unit.

Area #2

Line	Direction	Response
500	NW to SE	Power line effects from Station 00 to 75; no definitive response, but Station 775-800 may represent the northwest edge of the shale unit. Shales noted in outcrop at Station 860.
600	SE to NW	Crossover at Station 100 may correlate with shale unit boundary. There is a 100 nT magnetic anomaly at Station -25; the traverse was not extended farther due to swampy conditions.
700	SE to NW	Graphitic shale unit may exist between Stations 650 and 915 - however the response is poorly defined.
800	NW to SE	Northwest edge of shale unit appears to be located at Station 175; the traverse did not extend beyond the southeast edge.
900	E to W along road	Poor record due to obliqueness of angle between road traverse direction and strike of interpreted unit.

Table 2. Summary of Rock Samples

Sample Number	Rock Type
1	Graywacke
2	Graywacke
3	Graywacke
4	Graywacke
5	Graywacke
6	Graywacke
7	Graywacke and shale
8	Shale
9	Shale
10	Graywacke

CONCLUSIONS

The traverses conducted over Area # 1 provide definitive and positive evidence of a conductor, lying southeast of the presently indicated position of the shale unit. The stratigraphy of the Badger map area indicates rock units young to the north; however, a Llanvirnian-Llandeilian limestone unit has been identified on the northwest side of the conductor (Kean and Jayasinghe, 1982). This implies that either the conductor is not the Caradocian shale unit or that the rocks have been structurally juxtaposed such that the older limestone unit overlies the shale. Further geological field work is required to sort out this problem. As an assessment of the airborne VLF-EM data, the ground follow-up has confirmed that it is an effective tool for tracing conductive units.

Area #2 represents a much less conclusive test case, as the field work was limited by inaccessability due to power lines, swamps, and dense vegetation. However, the marginally anomalous character of the ground data supports the apparent lack of localized response on the airborne VLF-EM data. It is thought that the Caradocian interval in the western part of central Newfoundland is marked by not one, but a number of shale/chert units separated by coarse grained clastic rocks (graywacke); for further details see Kean and Jayasinghe (1982) and Dean (1978). The complexity of such a sedimentary sequence would explain the ambiguity seen in both the airborne and ground VLF-EM data.

In summary, well-defined anomalies on airborne VLF-EM data appear to be good indicators of conductive units, such as the Caradocian graphitic shale unit found in the Badger map area.

ACKNOWLEDGEMENTS

Ambrose Howse was an enthusiastic and helpful proponent of the work in the Port au Port Peninsula area. Baxter Kean was most helpful in initiating me to the geology of the Badger map area, as well as verifying the rock sample identifications. Both Ambrose and Baxter are thanked for critically reviewing this paper.

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*Current Research (1986) Newfoundland Department of Mines and Energy
Mineral Development Division, Report 86-1, pages 251-256*

GRAVITY SURVEYS IN INSULAR NEWFOUNDLAND, 1985

Hugh G. Miller [1]
Geochemistry and Geophysics Section

INTRODUCTION

Gravity surveys were conducted as a co-operative project between the Department of Mines and Energy and Memorial University. Data were collected in five areas: Indian Bay Pond area of the northern Gander Zone, Ackley Granite area, Third Berry Hill Pond area, along the Burgeo road, and along a profile traversing the Mount Cormack Terrane (Figure 1).

All data were collected using a Lacoste - Romberg land gravity meter, G172. Elevations were determined by Wallace and Tiernan barometric altimeters using known topographic control elevations as bench marks. All elevations were tied to mean sea level by surveying from the water line and were corrected with reference to tide tables. Positions were taken from 1:50,000 scale topographic maps.

A total of 619 gravity readings were taken at 593 localities in the five areas surveyed, and 26 were at repeat stations. The data were reduced to Bouguer anomalies through the use of standard Canadian Network gravity bases which are in turn tied to the worldwide IGSN71 network. The theoretical gravity at each station was determined using the 1968 International Gravity Formula, and a crustal density of 2.67^{-3} g cm was used for the Bouguer slab correction. No terrain corrections were considered necessary. The resulting Bouguer anomalies are considered accurate to ± 0.5 mGal with the main contribution to the uncertainty arising from the 2 m uncertainty in the elevation, although in the Ackley Granite survey this accuracy deteriorates to ± 1 mGal due to an elevation uncertainty of ± 5 m.

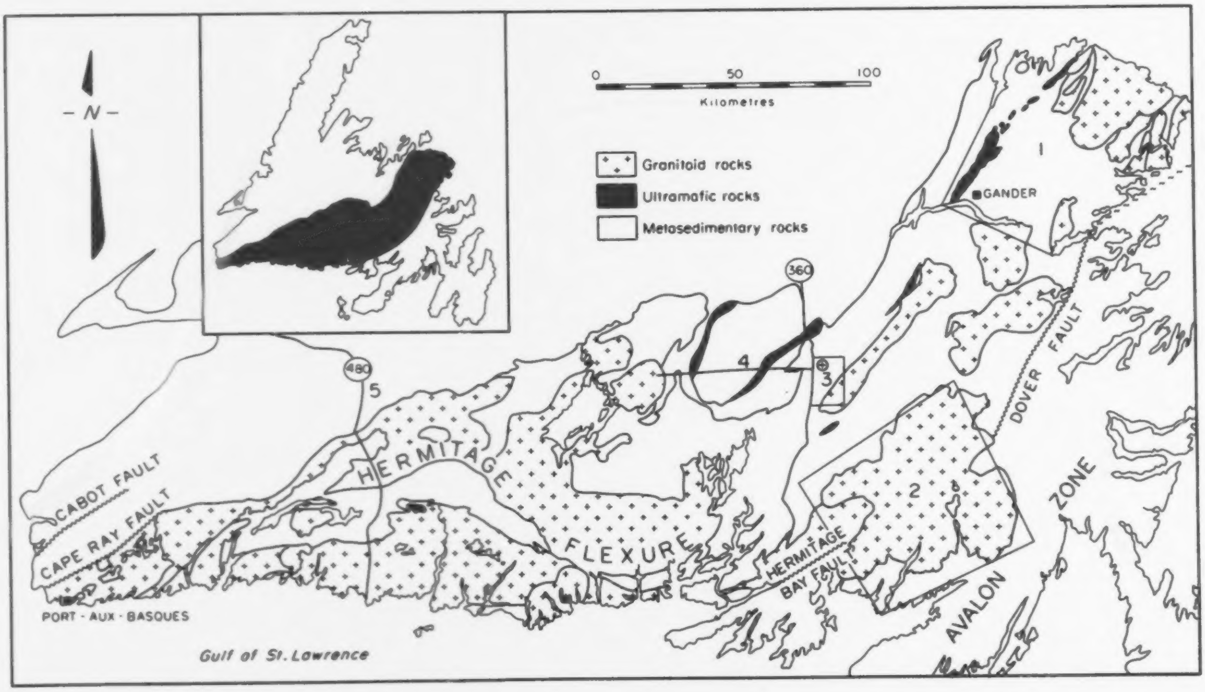
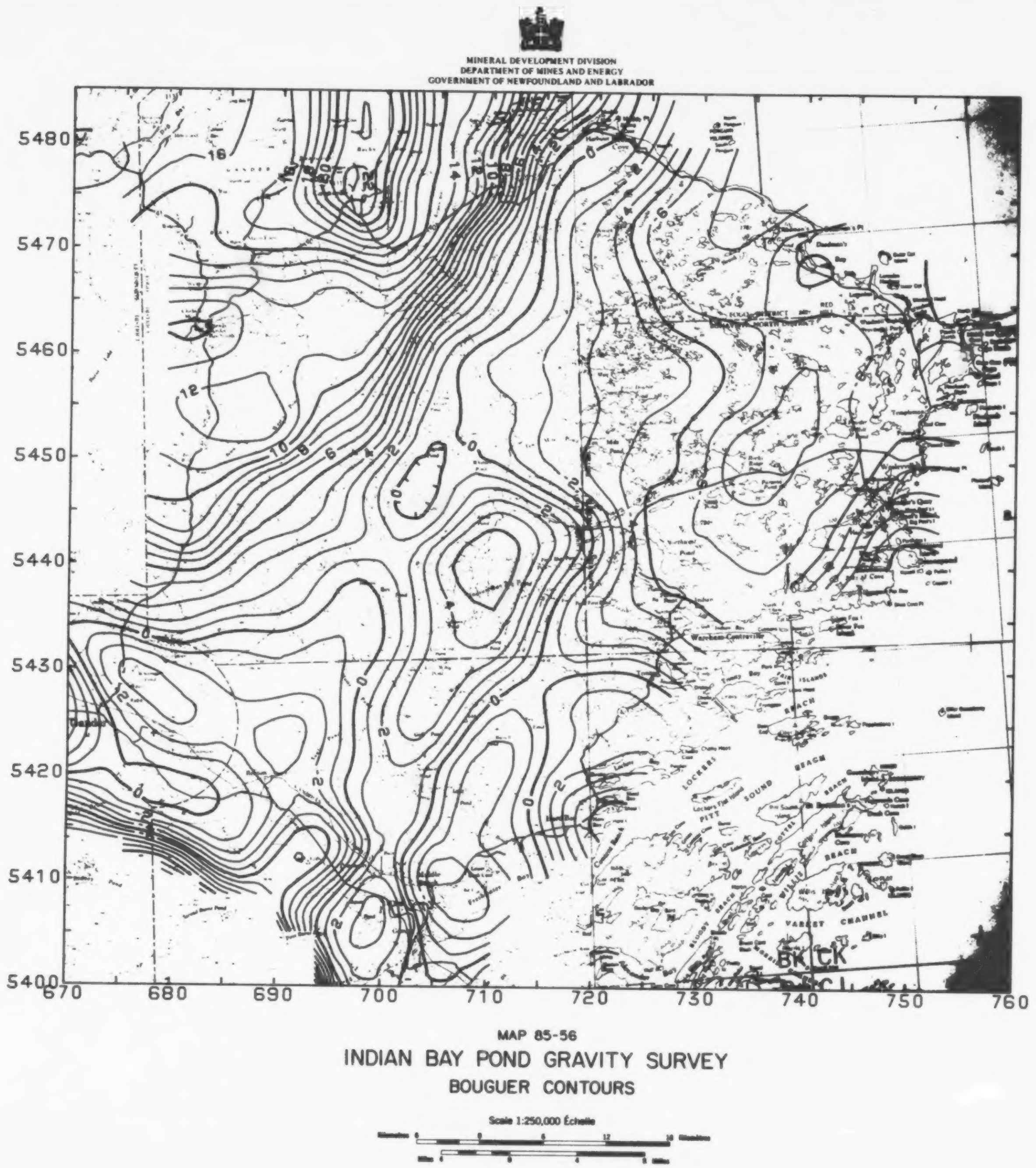


Figure 1: *Simplified geological map and survey location map for 1985 gravity surveys. Area 1 - Gander; Area 2 - Ackley Granite; Area 3 - Third Berry Hill Pond; Area 4 - Mount Cormack Terrane; Area 5 - Burgeo road.*

This project is a contribution to the Canada-Newfoundland Mineral Development Agreement, 1984-1989.

[1] On sabbatical leave from the Department of Earth Sciences, Memorial University of Newfoundland.


MINERAL DEVELOPMENT DIVISION
DEPARTMENT OF MINES AND ENERGY
GOVERNMENT OF NEWFOUNDLAND AND LABRADOR
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670
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690
700
710
720
730
740
750
760
MAP 85-56
INDIAN BAY POND GRAVITY SURVEY
BOUGUER CONTOURS
Scale 1:250,000 Échelle

Figure 2: *Bouguer anomaly contour map for Indian Bay Pond area. Co-ordinates are UTM Zone 21 co-ordinates in kilometres; contour interval 2.5 mGal.*

Indian Bay Pond Area

The Indian Bay Pond (Area 1, Figure 1) survey was conducted to provide additional geophysical data for delineating the belt of positive anomalies discovered by Miller and Weir (1982) and confirmed by a later pilot gravity survey (Butler *et al.*, 1984). During the 1985 field season an additional 251 stations were occupied in the area between the Trans Canada Highway in the south and Hamilton Sound in the north, and between the Gambo-Wesleyville road (Route 320) in the east and the Gander Bay road (Route 330) in the west (Figure 2). These data were compiled with the existing data collected by Weir (1971), Weaver (1967), and Miller (Miller and Weir, 1982), and released in open file form (Open File Nfld 1486).

The Bouguer anomaly map for the area is presented in Figure 2. Preliminary interpretation of the data, including aeromagnetic and geochemical data, indicate that the zone of positive Bouguer gravity anomalies commencing at co-ordinates 5400,710 can be followed northward to the vicinity of co-ordinates 5450,710, where they are abruptly terminated against the southern portion of the Deadman's Bay Granite (Strong *et al.*, 1974). These gravity anomalies have a coincident magnetic low in the north where there are also geochemical anomalies in copper, nickel, lead, cobalt and zinc. These anomalies occur in an area of limited outcrop in which there are some volcanic rocks and associated volcaniclastics (Blackwood, 1978; Wonderley and Neuman, 1984). The gravity anomaly containing a steeper eastern gradient in the vicinity of coordinates 5440,710 supports the thrust interpretation of Wonderley and Neuman (1984). The continuity of the anomaly pattern southward suggests that the volcanic rocks occur in the positive anomaly belt and extend to the southern boundary of the study area.

The combined geophysical and geochemical signatures associated with particular geological units in this study suggest that the combining of regional surveys may be a powerful tool in interpreting the geology in areas of limited outcrop. This point will be pursued further in interpreting the data using statistical correlation methods. The data will also be interpreted using standard geophysical modelling techniques to determine the attitude and subsurface extent of a possible thrust slice.

Ackley Granite Area

A pilot survey was carried out in 1983 (Miller, 1984) to determine the subsurface extent of the Ackley Granite using gravity data along two main traverses. To complement this survey, 131 stations, spaced 5 km apart along six traverses, were occupied across the granite during the 1985 field season, adding to the existing data base of 52 stations occupied in 1983 (Area 2, Figure 1). The Bouguer anomaly contour map resulting from the complete data set, which has been released as Open File Nfld 1487, is presented in Figure 3. The data demonstrate that the gravity field over the granite varies considerably and exhibits correlation with the various map units determined by Dickson (1983) and O'Brien *et al.* (1984). In particular, the region in which the roof pendants are found (in the vicinity of coordinates 5315,670) is the location of a relative gravity high, indicating that the granite is much thinner there. The thickest portion of the granite is in the southwestern part of the study area where the gravity anomalies are as low as -19.7 mGal. This thicker portion of the granite extends north with another pronounced gravity low centered at 5325,650. Between this low and the southern low, there is a ridge in the gravity data which approximately coincides with a major boundary in the geochemical trends and in the geological units (Dickson, 1983; O'Brien *et al.*, 1984). The trace of the Dover Fault (Blackwood and O'Driscoll, 1976) and its assumed continuation, the Hermitage Bay Fault, are readily recognized by the linear patterns in the southwestern and northeastern parts of the survey area.

The aeromagnetic data for the area are being digitized and will be processed and used to interpret the boundaries of the granite where no gravity data are available. The magnetic susceptibility and density have been determined for all the samples used in the geochemical assessment of the area (Dickson, 1983; Tuach, 1984), enabling the complete geophysical and geochemical data bases to be used in the interpretation of the area. The statistical correlations between these data will be examined to further develop techniques of assessing combined geophysical and geochemical regional data. Geophysical modelling and inversion methods will be used to ascertain the subsurface configuration of the granite. The general conclusion, based on the preliminary interpretation, is that there is an excellent correlation between the geological and geophysical data. This will ensure that the interpreted thickness for various portions of the area will be reliable, especially since the physical properties are so well known.

Third Berry Hill Pond and Mount Cormack Terrane Area

Gravity data were collected during 1985 at 56 stations in the Third Berry Hill Pond area (Area 3, Figure 1). These data were supplemented by data from a previous survey to produce the Bouguer anomaly map for the area (Figure 4; Open File 2D (155)). The objective of this survey was to collect sufficient data over the Third Berry Hill Pond granite (Blackwood, 1983) to determine the surface and subsurface extent of the granite using geophysical methods in an area of poor exposure. A preliminary examination of the gravity, magnetic, and geological data suggests that the granite extends in the subsurface to the southwest. The combined geophysical data indicate that the boundaries of the other geological units may also be better determined. Further interpretation will be conducted when the data from other reports on the area are incorporated into the data base.

An additional 22 stations were occupied along an east-west line from the Bay D'Espoir highway (Route 360) west to Great Burnt Lake to examine the gravity signature of the Mount Cormack Terrane (Colman-Sadd and Swinden, 1984). These data will be combined with the aeromagnetic data to model the subsurface extent of the ophiolitic bodies in the area. Preliminary examination of the gravity data indicates that the gravity high regions correlate, as expected, with the areas of known ophiolite outcrop.

Burgeo Road Area

A survey consisting of 159 stations at 1 km spacing was conducted along the Burgeo road (Area 5, Figure 1) to examine the correlation between the gravity data and the geologic units. The anomalies are negative for the first 12 km east from the intersection of the Burgeo road (Route 480) and the Trans Canada Highway, beyond which the anomalies are positive for 70 km. Within the latter region there are two zones of positive anomalies in excess of 25 mGal, one located approximately 25 km from the western end of the road and the second over the Annieopsquotch Mountains. South of the mountains the gravity anomalies are all negative. The Bouguer anomalies on this survey range from+31.9 mGal to −28.1 mGal. The gravity, magnetic, and geological data from this area will be combined to determine a crustal model for southwestern Newfoundland.

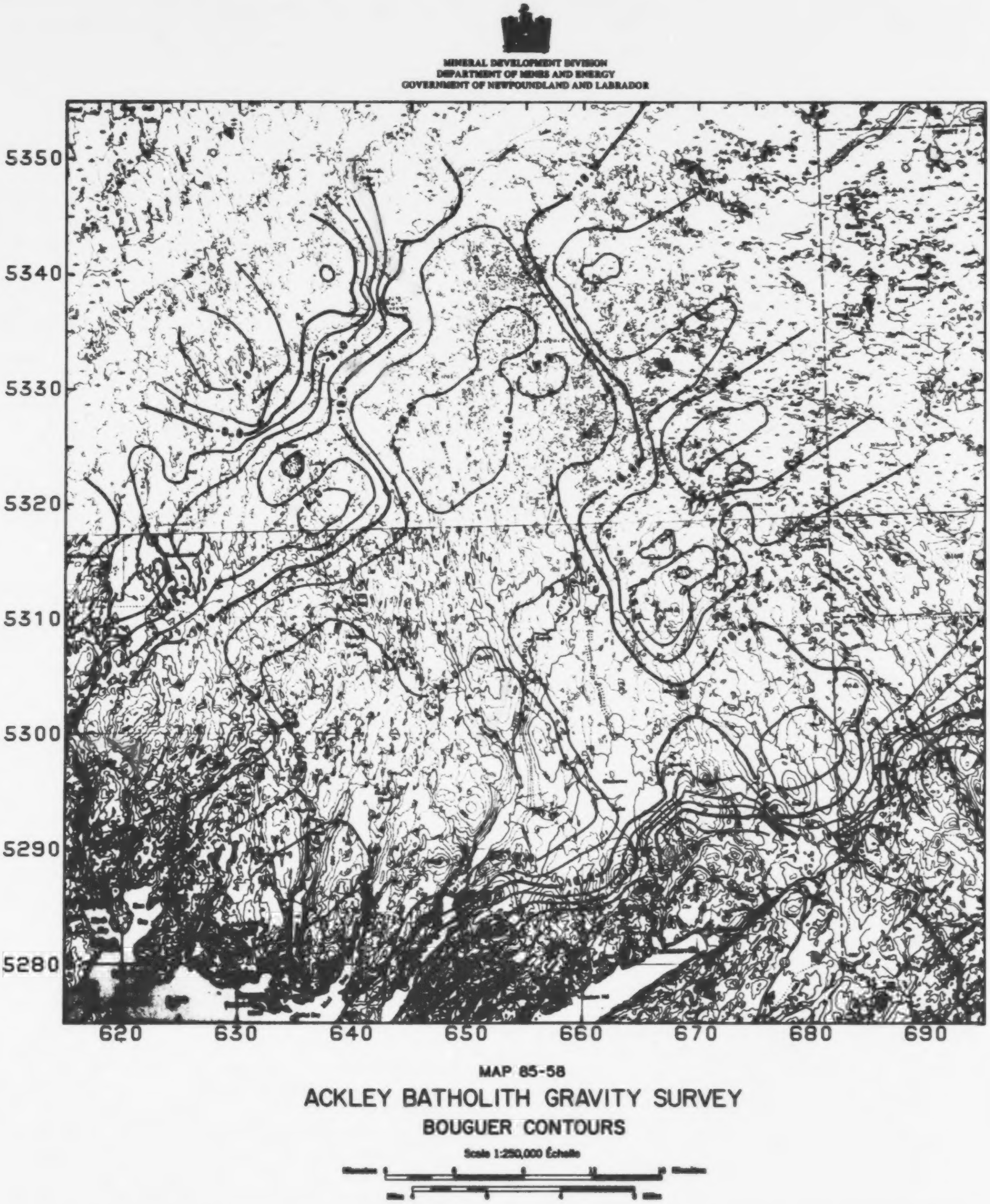
MINERAL DEVELOPMENT DIVISION
DEPARTMENT OF MINES AND ENERGY
GOVERNMENT OF NEWFOUNDLAND AND LABRADOR
5350
5340
5330
5320
5310
5300
5290
5280
620
630
640
650
660
670
680
690
MAP 85-58
ACKLEY BATHOLITH GRAVITY SURVEY
BOUGUER CONTOURS
Scale 1:250,000 Échelle

Figure 3: *Bouguer anomaly contour map for Ackley Granite area. Co-ordinates are UTM Zone 21 co-ordinates in kilometres; contour interval 2.5 mGal.*

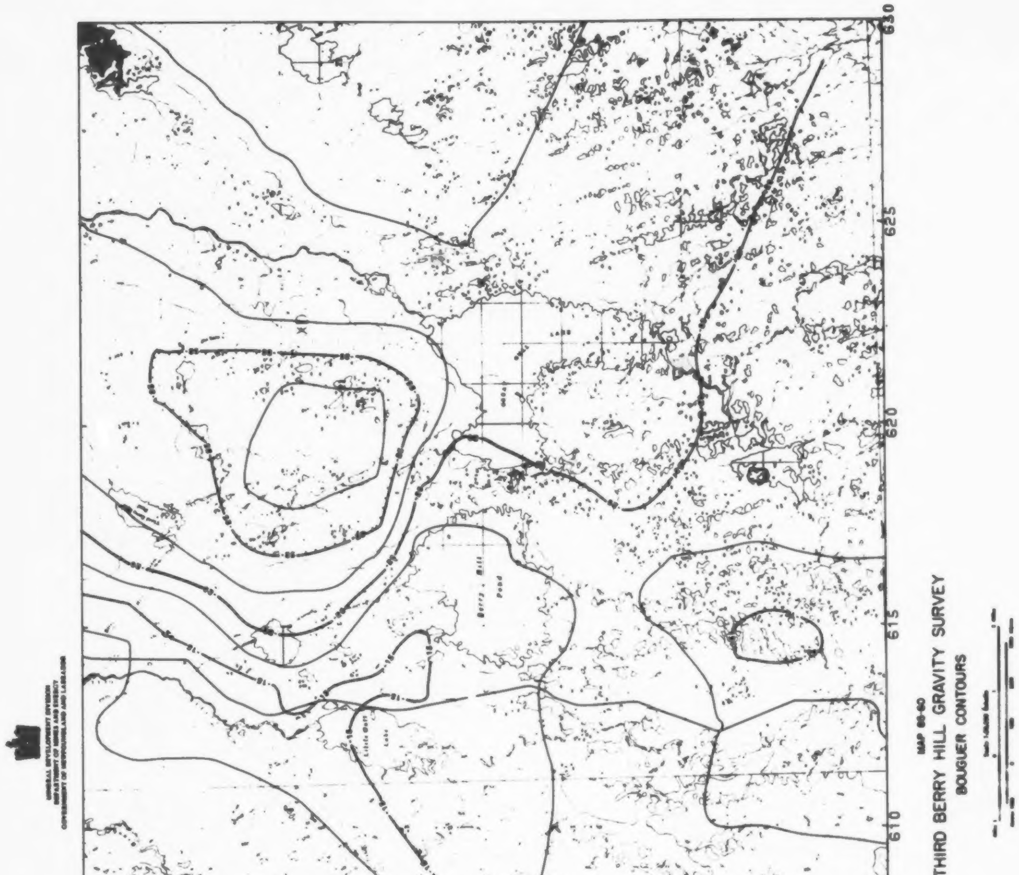
MINERAL DEVELOPMENT DIVISION
DEPARTMENT OF MINES AND ENERGY
GOVERNMENT OF NEWFOUNDLAND AND LABRADOR
MAP 85-60
THIRD BERRY HILL GRAVITY SURVEY
BOUGUER CONTOURS
Berry Hill Pond
Little Gull Lake
5365
5360
5355
5350
5345
595
600
605
610
615
620
625
630

Figure 4: *Bouguer anomaly contour map for Third Berry Hill Pond area. Co-ordinates are UTM Zone 21 co-ordinates in kilometres; contour interval 2.5 mGal.*

Bouguer anomalies determined from all except the Burgeo road data have been released in Open File reports which also contain the gravity data from previous Memorial University and Earth Physics Branch surveys in the various areas. Publications dealing with the detailed interpretation of the various data sets are planned.

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QUATERNARY EXPLORATION AND SURFICIAL MAPPING IN THE LETITIA LAKE AREA, LABRADOR

Martin Batterson and Paul LeGrow
Quaternary Geology Section

ABSTRACT

Investigations in the Letitia Lake area focused on 1:50,000 scale terrain mapping of the northern half of 13L/1 and the southern portion of 13L/8 and detailed Quaternary exploration around Two-Tom Lake. Terrain mapping focused on ground verifying an air photograph interpretation; till sampling and locating ice flow indicators. Evidence of three flows was found, all probably related to the Late Wisconsin, with the latest flow being generally west to east (072-080). Detailed studies followed up a previously reported radiometric anomaly that was confirmed by an airborne scintillometer survey. A ground program, consisting of bedrock and boulder mapping, identified two distinct, mineralized, syenite-gneiss, boulder trains and several areas of previously unmapped mineralized bedrock. In addition, a ground scintillometer survey was used to enhance the airborne survey, and a biogeochemical program was initiated with the aim of defining dispersal patterns.

INTRODUCTION

The Letitia Lake area (Figure 1) has been the focus of significant exploration activity since 1956 when Kennco Exploration Ltd. discovered the Mann deposits, following a stream geochemistry survey (Brummer, 1957; Evans and Dujardin, 1961). The Mann # 1 deposit is thought to contain over 6.8 million tonnes of BeO, although problems with beneficiation renders the deposit uneconomic under present conditions (Gaines, 1977).

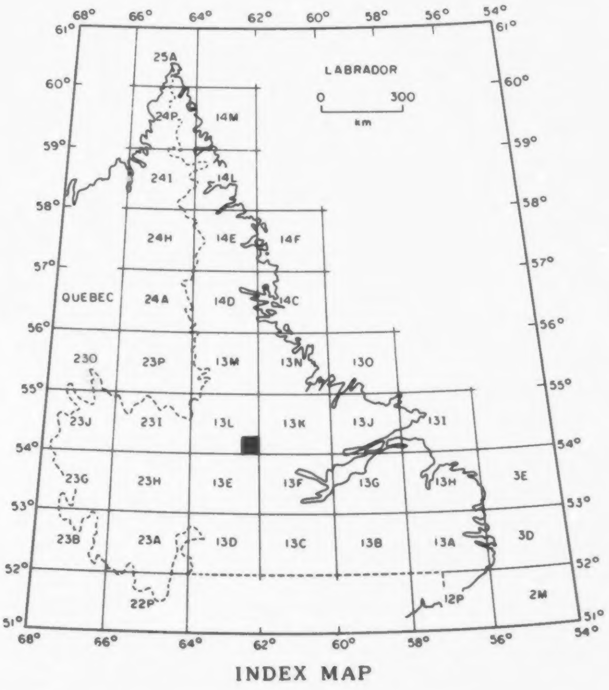

Figure 1: *Location of field area.*

Interest in other areas around Letitia Lake was generated by a Barringer airborne radiometric survey which identified a series of anomalies (Boniwell, 1967). One of these, around Two-Tom Lake (Figure 2), received some attention when Brinex followed up on a report that rock types in the area contained over 2 percent total rare earths, and up to 1 percent Nb and 1 percent Be (Westoll, 1971). However, Brinex was unable to reproduce these values and therefore concluded that the area was uneconomic. Nevertheless, interest in the Letitia Lake region has been rekindled with two companies, Richard Gaines and Maritec, acquiring claims in the Mann deposit area. This exploration activity, the possibility of locating other mineralized sources in the Two-Tom Lake area, and the opportunity for discerning dispersal patterns prompted this current project.

Scope of Project

Quaternary research activity in Labrador has traditionally been negligable. Recently, however, the Newfoundland Department of Mines and Energy and the Geological Survey of Canada have introduced programs. The federal survey has concentrated on 1:250,000 mapping, while the provincial department has carried out 1:50,000 scale terrain mapping, supplemented by detailed Quaternary exploration programs. This current project focuses on two specific aspects of the Letitia Lake area: 1) regional till sampling and terrain mapping of a 480 km² area comprising the northern half of map area 13L/1; the southern portion of map area 13L/8 was studied to generate an overview of dispersal patterns and ice flow directions, and 2) a detailed, drift-exploration survey

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This project is a contribution to the Canada-Newfoundland Mineral Development Agreement, 1984-1989

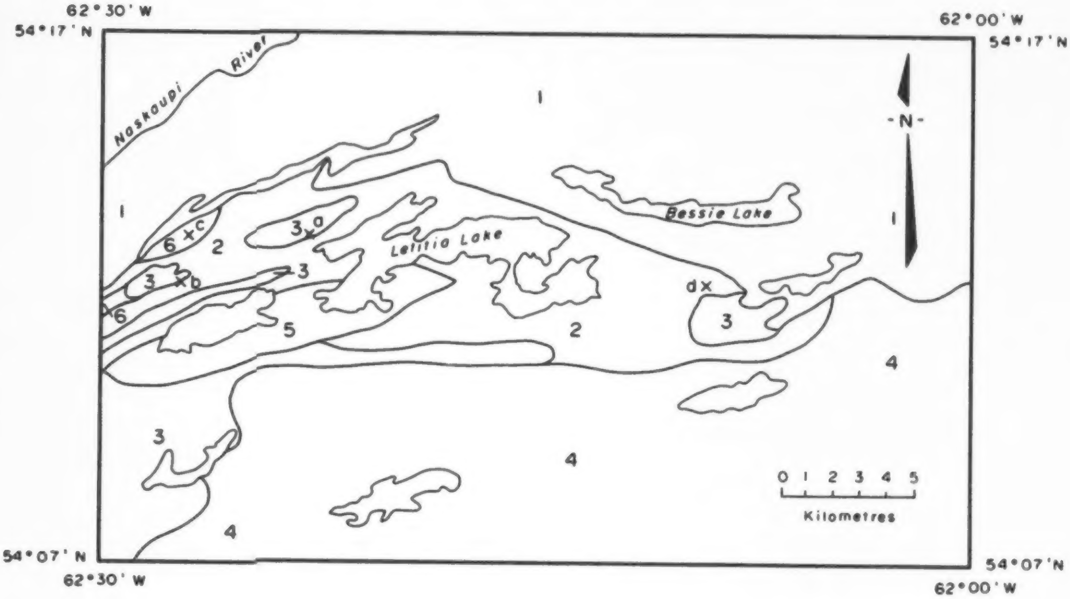
in the Two-Tom Lake area. Each aspect will be discussed separately.

Regional Setting

Letitia Lake (54° 15′ N 62° 20′ W) is situated 160 km northwest of Goose Bay, Labrador. Access is by fixed-wing aircraft or helicopter. Physiographically, the area may be subdivided into two broad regions (Lopoukhine *et al.*, 1977). The 'Postville Land Region', north of Letitia Lake, is an area of parallel bedrock ridges up to 500m in elevation, and broad, glacially-enlarged valleys. The 'Nipishish Lake Land Region' to the south is a plateau area dominated by glacial sediments, bedrock outcrops and numerous areas of bogs. Both regions have a continental climatic regime, are within the boreal forest zone (Rowe, 1972), and lie within the zone of discontinuous permafrost.

General Geology

The Letitia Lake area lies just south of the boundary between the Churchill and Grenville provinces, along the southern margin of the Grenville Front. The area has been studied in detail by Thomas (1981) and Curtis and Currie (1981), and the following description is based on their work (Figure 2). The Letitia Lake Group underlies the Letitia Lake region, including the Two-Tom Lake area. The group consists of massive quartz-feldspar porphyry at its base, overlain by a sequence of porphyritic rhyolite, banded rhyolite, crystal tuff and ignimbritic tuff, and an upper regolith derived from the underlying units. The Letitia Lake Group is in fault contact to the north with rocks of the Seal Lake Group. The Seal Lake Group consists of siltstone, shale, argillite and interbedded chert of the Wuchusk Lake Formation, and porphyry-cobble conglomerate, quartzite and basaltic flows of the Bessie



LEGEND

1 Seal Lake Group
2 Letitia Lake Group
3 Arc Lake Intrusive Suite
4 North Pole Brook Intrusive Suite
5 Porphyritic rhyodacite
6 Red Wine Alkaline Intrusive Suite

Mineral Prospects:
a - Mann # 1
b - Mann # 2
c - Michelin # 1
d - Two-Tom Lake

Figure 2: *Generalized geology of the Letitia Lake area.*

Lake Formation. Alkali syenites, alkali feldspar porphyry and peralkaline granite of the Arc lake Intrusive Suite, and granodiorite-quartz monzonite, biotite granite and diorite of the North Pole Brook Intrusive Suite occur south of the Letitia Lake Group.

Mineral Deposits

Four mineral prospects occur within the study area. The Mann # 1 deposit, located within the Arc Lake Intrusive Suite, has anomalous radioactivity and contains an average ore grade of 0.35 to 0.40 percent Be0, within barylite and eudidymite minerals. Niobium is an important secondary mineral. The Mann # 2 deposit, located 5.6 km southwest of Mann # 1, is within an Arc Lake Intrusive Suite inlier, and contains similar minerals. Assay values are lower than the Mann # 1 deposit (Brummer, 1957). The Michelin # 1 property occurs to the north of Mann # 2 deposit and is developed within the green pyroxene-aenigmatite gneiss of the Red Wine Alkaline Intrusive Suite. It has anomalous radioactivity and contains low assay values of Nb_20_3 (Robinson and Cruft, 1958). The fourth prospect, in the vicinity of Two-Tom Lake, was identified through an airborne radiometric survey and comprises several areas of radioactive boulders. The boulders are predominantly alkali gneiss (Deane, 1970) and occur within the quartz-feldspar porphyry terrane of the Letitia Lake Group. The main mineralization is REE (Rare Earth Elements) bearing minerals, and Be and Nb minerals are accessories (Westoll, 1971). Of the four prospects, none are considered to be economic at present. However, if retrieval techniques are improved, the economic status of the area may be enhanced.

LETITIA LAKE: THE QUATERNARY ENVIRONMENT

Terrain Analysis

An interpretation of the surficial geology was made of map sheet 13L/1 and the southern portion of 13L/8 using 1:50,000 scale black and white airphotos. The resultant map was extensively field checked and is summarized in Figure 3. It shows that the terrain may be subdivided into five broad categories, similar to those defined by Fulton *et al.*, (1975). The area north of Letitia Lake is almost entirely dominated by bedrock ridges underlain by the Seal Lake Group, although numerous areas of till veneer occur between the ridges. South of Letitia Lake, the change in rock types is reflected by a change in topography, to an undulating plateau containing numerous areas of bog, scattered outcrops, and till of varying thickness, generally having a fluted appearance. The major valleys, notably the Red Wine and Naskaupi Rivers, are dominated by glaciofluvial outwash deposits. The outwash facies vary from sand plains of varying thickness which commonly flank well-defined eskers that reach heights of 3 to 5 m. The Letitia Lake valley is an exception to the outwash-dominated valleys. Although eskers are evident here, they are generally poorly developed, dissected and covered with a veneer of large boulders, many greater than 2 m in diameter. Till of varying thickness, locally exceeding 3 m, commonly has a ridged or hummocky surface expression. Numerous erosional channels, which enter the valley from its northern and southern margins, are also developed.

Sampling Methods

Till sampling was carried out over the study area for two purposes: 1) to determine dispersal patterns through geochemical analyses, especially from areas of known mineralization, and 2) to generate data on transport distances and directions through lithological analyses.

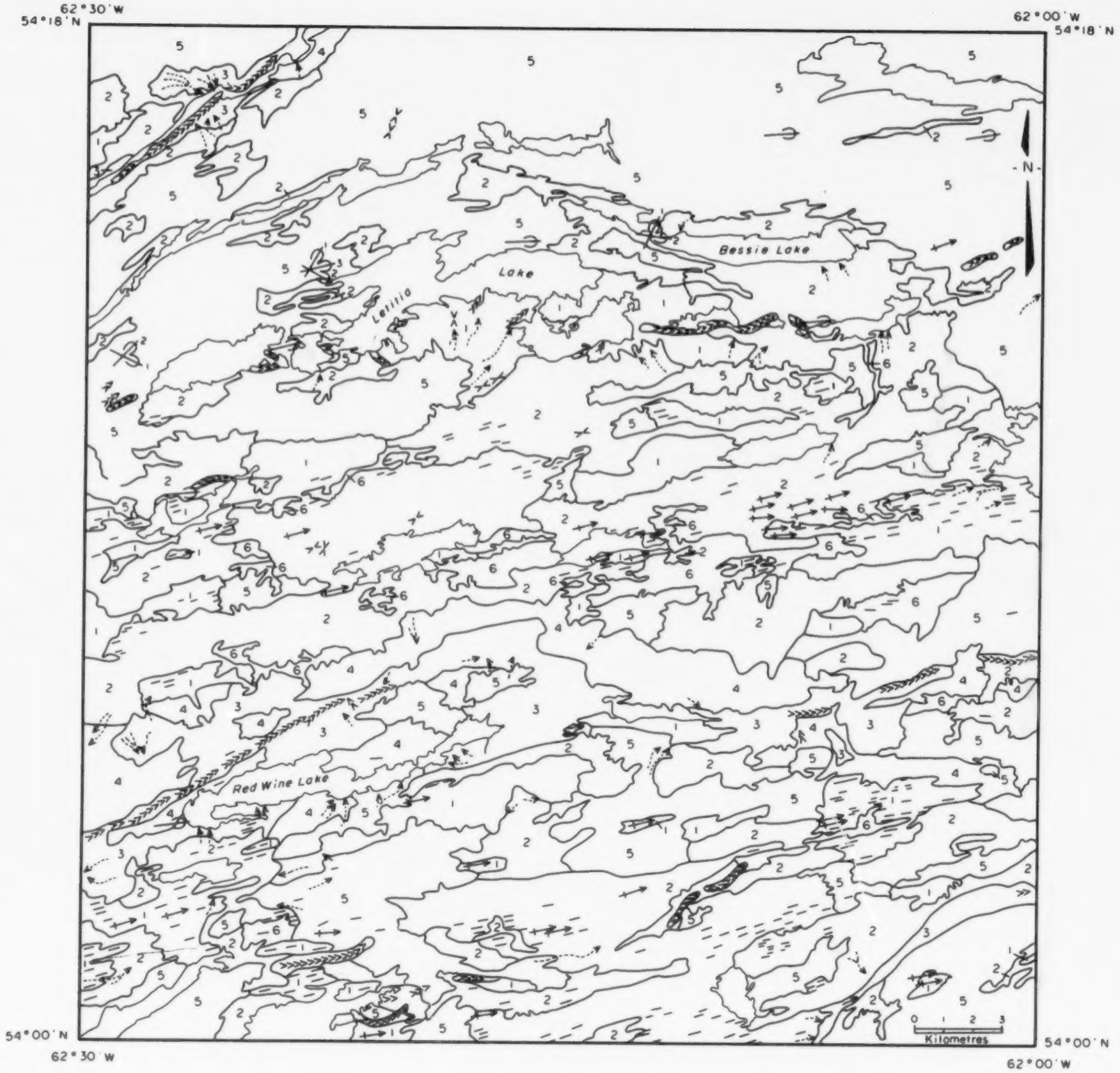
The sampling program was completed during a two week period on a 2 x 2 km grid. At each site, a sample was taken of the least oxidized horizon at the base of a pit. If possible, this was the C horizon, although commonly either iron-staining, large boulders or bedrock interrupted the pit, in which case either the BC or B horizon was sampled. At several sites, where a complete soil profile was observed, samples of each soil horizon were taken. At each site, lithological samples comprising 50 to 100 pebbles were taken from the coarser than 16 mm size fraction. These were identified with the aim of matching them with known source areas. In total, 225 till samples from 195 sites were collected.

Bedrock outcrops in the vicinity of each site were examined for glacial striations or other ice flow directional indicators, e.g., crescentic gouges, and their azimuth measured. In total 15 sites revealed such information.

Preliminary Interpretation of Glacial History

Previous workers have considered the Letitia Lake area only in a regional sense, and no detailed Quaternary work has been undertaken since the area lies in the central part of the Labrador sector of the Laurentide dispersal area. Prest *et al.* (1968) describes the general dispersal pattern of Late Wisconsin ice as flowing through the Labrador Trough and then trending approximately eastward or northeastward, probably following the line of least resistance along the Grenville Front (Rogerson, 1981). Recession is poorly understood in this part of Labrador. Ives (1960) suggests that ice on the Northern Labrador plateaux stagnated and down-wasted, while in the larger valleys gravity drainage helped maintain an active ice flow. In the Central Labrador region, the lack of recessional features may be an indication of stagnation.

Several observations are significant in a discussion of glacial advance and retreat within the study area. Evidence from directional indicators, notably striae (Figure 3), show that three ice flow events affected the area. The earliest flow, preserved in the lee of later events, trends 046. The consistency of this trend throughout the area, oblique to the topographic grain, suggests that it was a major event. The second flow ranges from 096/098 in the south to 114 in the north. The dominant flow event, based on striae and glacial landform evidence, is 074 in the north and ranges to 080 in the south. Earlier striae are always preserved in the lee of later events and crossing striae were rarely observed. The lack of a glacial stratigraphy and dateable material means the age of each of these flow events is open to conjecture. However, the fact that no set of striae showed any evidence of weathering and that each was observed within glacial polish suggests that all flows could be related to the same


62°30'W
54°18'N
62°00'W
54°18'N
N
Bessie Lake
Letitia Lake
Red Wine Lake
54°00'N
62°30'W
54°00'N
62°00'W
0 1 2 3
Kilometres

LEGEND

1 Till (>3m)

2 Till (<4m)

3 Glaciofluvial outwash (>3m)

4 Glaciofluvial outwash (<3m)

5 Mostly bedrock

6 Organics

Meltwater channel

Esker (direction known/ direction unknown

Fluted / lineated till

Crag and tail

Glacial striae (1 = oldest)

Figure 3: *Surficial geology map of the Letitia Lake area*

event, presumably the Late Wisconsin. All glacial landforms, e.g., flutes, crag and tails, are consistent with the last ice flow event, and it is expected therefore that patterns of geochemical and lithological dispersal should also be consistent with this flow.

Recession of the Laurentide ice sheet produced large quantities of meltwater. This is reflected by the extensive outwash deposits and eskers within both the Naskaupi and Red Wine River valleys, which coalesce to the east and exit into Grand Lake. It is perhaps due to its proximity to the altitudinally lower Naskaupi Valley, and the resultant drawdown, that the Letitia Lake valley shows evidence of only minor outwash and esker deposits. Apparently, Letitia Lake was an area of ice stagnation. Meltwater channels entering the valley add to the complexity of deposits here. Features within the valley, such as hummocky till, randomly oriented till ridges (crevasse fillings?), numerous meltwater channels, and poorly defined and discontinuous eskers, are consistent with ice-stagnation topography. The Letitia Lake valley is completely covered by a surface mantle of large (commonly greater than 2 m in diameter), angular boulders of predominantly local origin. However, few such boulders are noted on the plateau area to the south. A suggested explanation for this is that as glacial ice entered the head of the Letitia Lake basin, the subsequent movement down a concave surface resulted in an extending-flow regime. This regime enhanced erosion of the substrate and large blocks were quarried and entrained. Upon stagnation, the boulders were deposited upon the surface. The large amounts of meltwater caused winnowing of material from around the boulders, resulting in the present terrain. The lack of recessional features on the plateau implies that deglaciation was through a downwasting process.

TWO-TOM LAKE: DETAILED QUATERNARY EXPLORATION

Two-Tom Lake is situated within the Letitia Lake valley 5 km east of Letitia Lake. Physiographically, the area is a boulder-strewn lowland. Till appears to be generally less than 3 m thick; there are numerous small bogs and a well developed esker. Geologically, the area is dominated by quartz-feldspar-porphyry of the Letitia Lake Group. However, to the northeast of Two-Tom Lake, a northwest-southeast trending contact with the Bessie Lake Formation is inferred through aeromagnetic data (Sanger, 1971). An exploration program was adopted that would not only highlight areas of mineralization but also provide ice flow dispersal data. This facet of the project has four distinct components: an airborne scintillometer survey, a ground scintillometer survey, a biogeochemical survey and boulder tracing.

Airborne Scintillometer Survey

The purpose of this survey was to determine, in general, radiometrically anomalous areas that may reflect areas of

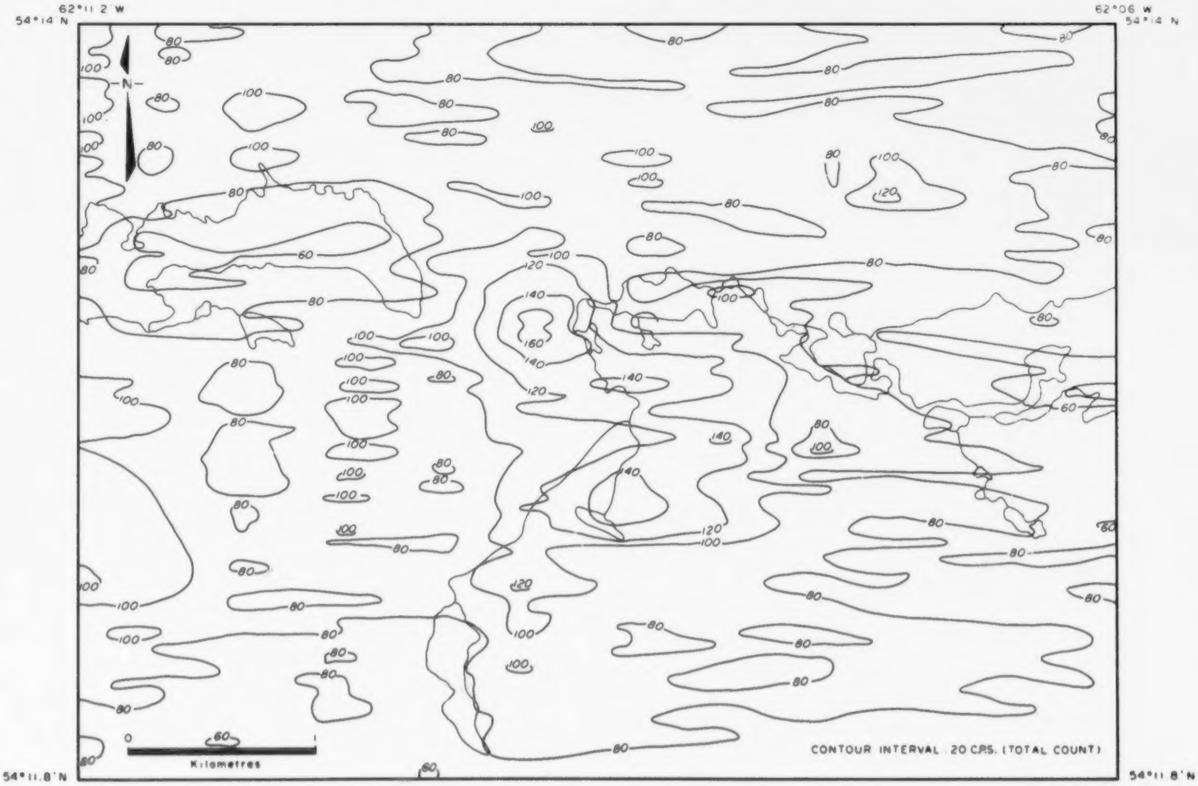


Figure 4: *Airborne scintillometer map of the Two-Tom Lake area.*

mineralization. The survey was completed using an EDA differential spectrometer, hand-held within a Bell 207B helicopter, flying at 100 km per hour, at an average height of 150 m. Readings were recorded every 1 second and subsequently transferred to a base map by calibrating values between known points (Figure 4).

The survey reveals several points of note: the major lows correspond to the lakes; patterns are elongated in a roughly west to east direction consistent with the regional glacial flow direction; a series of anomalies are present, the highest in the vicinity of Two-Tom Lake.

Ground Surveys

A survey grid was established on the basis of the airborne survey and reconnaissance ground traversing was done to determine the distribution of radioactive boulders. A 090 base line was established for a total length of 1200 m. Perpendicular grid lines were established every 100 m along the base line and extended an average of 500 m north and south with stations every 50 m. In total, 259 station sites were selected.

At each station a scintillometer reading was recorded (average of five), and the surrounding terrain mapped for

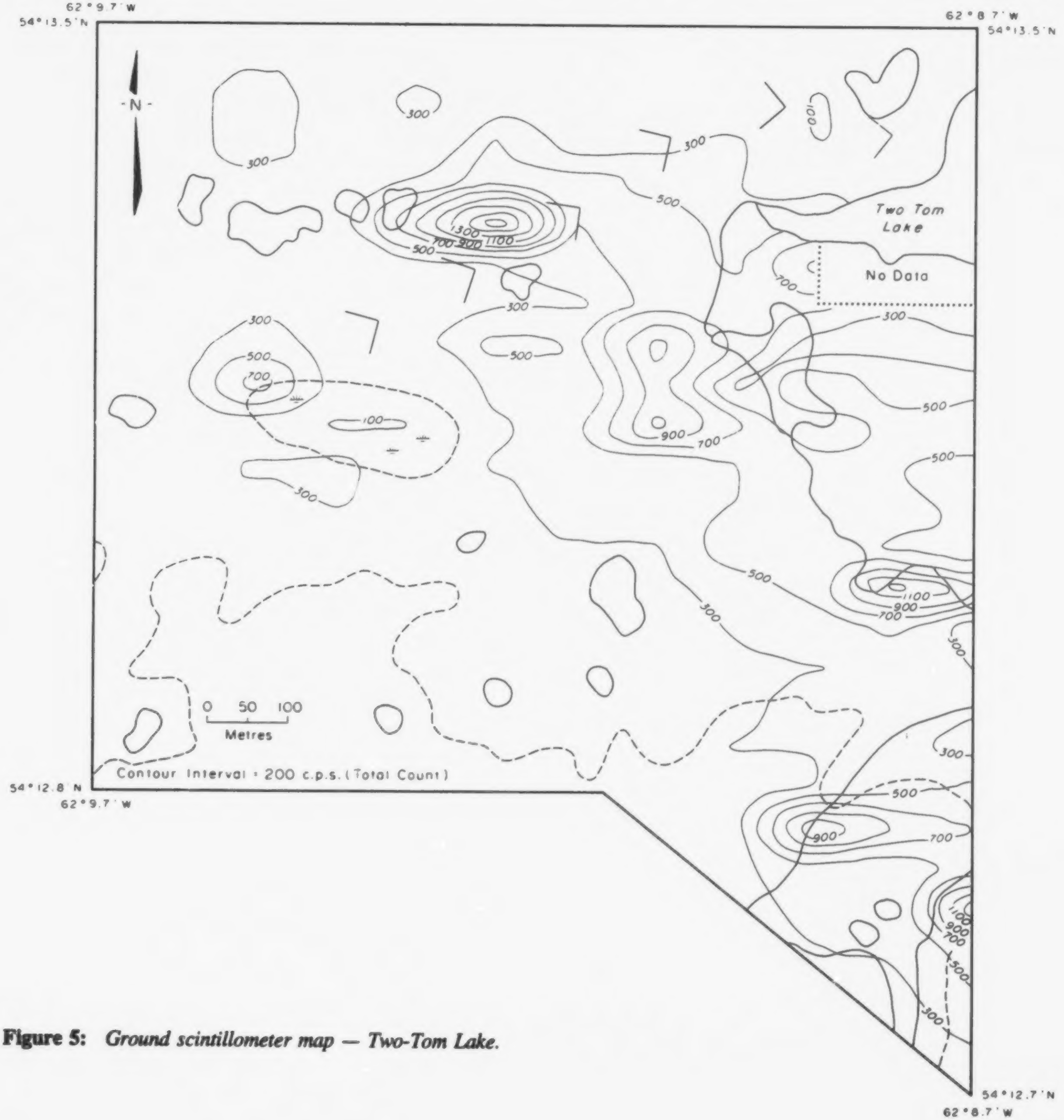

62° 9.7' W
54° 13.5' N
62° 8.7' W
54° 13.5' N
N
300
300
300
100
300
500
Two Tom Lake
1300
700
900
1100
500
No Data
700
300
300
500
300
500
700
100
300
900
700
500
500
500
300
1100
900
700
300
0 50 100
Metres
Contour Interval = 200 c.p.s. (Total Count)
300
500
900
700
1100
900
700
500
300
54° 12.8' N
62° 9.7' W
54° 12.7' N
62° 8.7' W

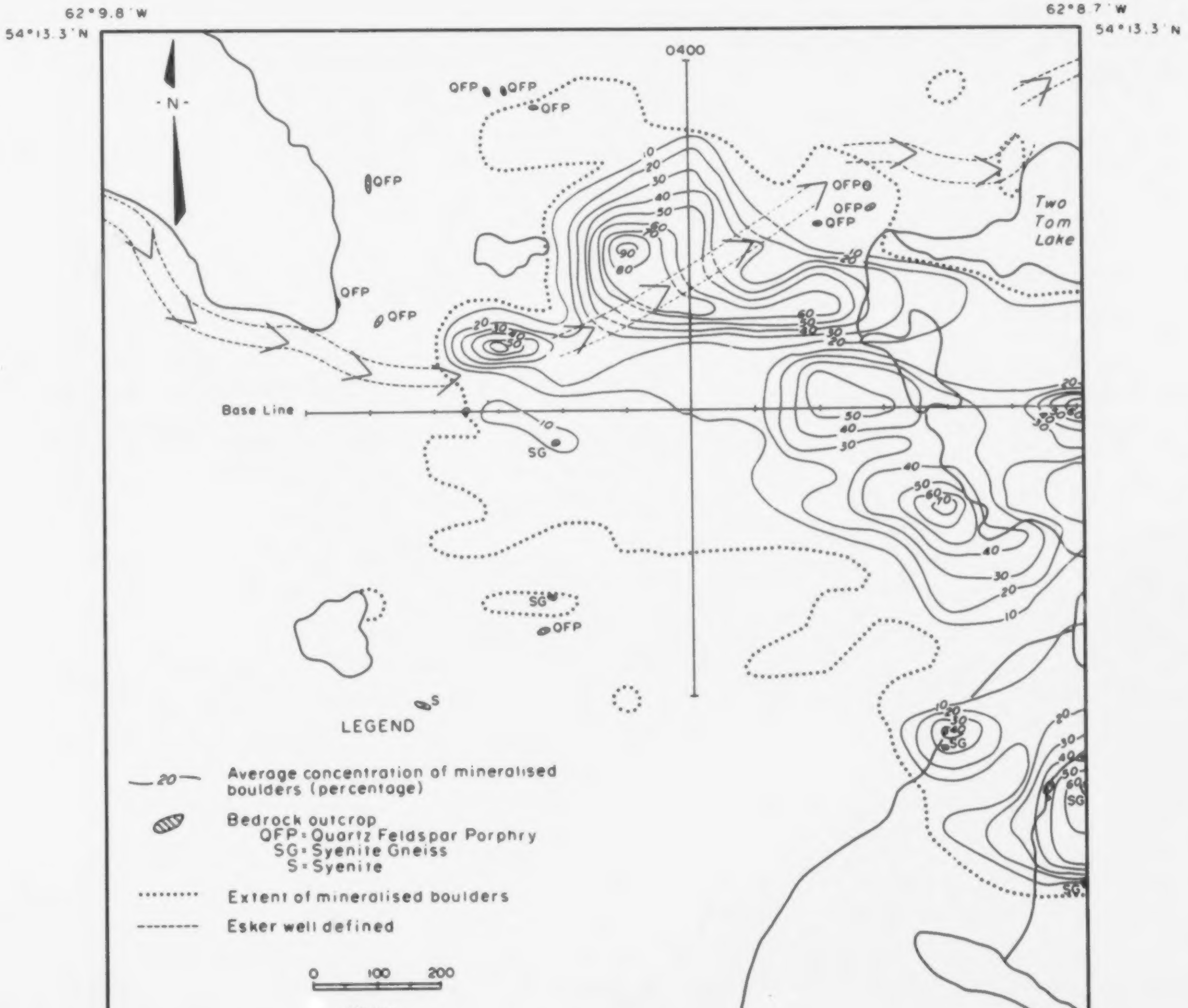
Figure 5: *Ground scintillometer map — Two-Tom Lake.*

bedrock outcrops, terrain type and mineralized boulders. Representative samples of both boulders and bedrock were taken for analyses. In all, 80 samples were collected.

The bouldery nature of the surface mantle and the discontinuous nature of the till made a till sampling program impractical. As an alternative, a biogeochemical method was selected. This method has been applied with moderate success by Dunn (1981, 1983) in the Athabasca basin in Saskatchewan, and by Kovalevsky (1972) in Russia. Dunn showed that, in general, highest values are attained from either black spruce *(Picea mariana)* twigs or Labrador tea *(Ledum groenlandicum)* roots. There is no shortage of the former in the Two-Tom Lake area. Samples were collected at every station following the methods outlined by Dunn (1981), i.e., 100 to 200 g of spruce twigs, approximately 25 cm in length (last 10 years of growth), were taken over a two day period in order to reduce the seasonal variations in chemistry noted in trees. The samples were air dried for 4 to 6 weeks in the laboratory, at which time the needles had fallen off. The twig samples were than ashed overnight in a furnace at 500°C.

Initial Results

The ground scintillometer survey (Figure 5) reveals the same general distribution of anomalous areas that were identified through the airborne survey. However, the ground survey does produce more detail in that it highlights a major anomaly in the southeast corner of the Two-Tom Lake area, and several highs to the north, east and west of this anomaly. These radiometric anomalies coincide almost perfectly with the distribution of mineralized boulders, which either occur singularly or as boulder clusters. A contoured percentage of the distribution of these mineralized boulders is shown in Figure 6.


62°9.8'W
54°13.3'N
62°8.7'W
54°13.3'N
54°12.6'N
62°9.8'W
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62°8.7'W
N
0400
QFP
SG
S
Two Tom Lake
Base Line
10
20
30
40
50
60
80
90
LEGEND
20 Average concentration of mineralised boulders (percentage)
Bedrock outcrop
QFP = Quartz Feldspar Porphry
SG = Syenite Gneiss
S = Syenite
Extent of mineralised boulders
Esker well defined
0
100
200
Metres

Figure 6: *Distribution of mineralized boulders around the Two-Tom Lake project.*

Two distinct dispersal trains are apparent from Figure 6. The southernmost train is composed of 90 percent foliated and banded syenite gneiss (sample number 854951, Table 1). Approximately 8 percent of the train is a gray-colored syenite gneiss containing a well developed gneissic fabric (sample number 854960). The remaining 2 percent of the train is composed of a medium grained syenite gneiss (sample number 854954), similar to the Mann # 1 host rocks.

The central dispersal train consists of three separate highs, each related to syenite gneiss of various textures. The southern and eastern highs consist of rocks designated as sample number 854960 and sample number 854951 respectively in Table 1. The western high predominantly contains a light gray to green syenite gneiss (sample number 854956) that is medium to coarse grained, but is less foliated and less radioactive (1000 cps) than the others. Dispersed throughout the train (up to 20 percent of total boulders) is a dark green, fine grained, massive, unfoliated rock type (sample number 854955) that is volcanic in appearance and has given readings up to 2600 cps. Several other varieties of syenite gneiss were also identified in the dispersal train, but all are of a minor nature.

The northernmost train is dominated (80 percent) by rocks described under sample number 854951 (Table 1). However, locally significant are those rock types represented by sample numbers 854954, 854955 and 854956 (Table 1). Of note, however, is the discovery within this train of a highly mineralized syenite-gneiss boulder producing greater than 60,000 cps.

It must be noted that although there are physical contrasts between syenite gneisses in the Two-Tom lake area and eight subdivisions have been made, chemical trends (yet to be determined) may not correspond to these subdivisions. Nevertheless, at least two major trains exist in the area.

SUMMARY

The type of exploration approach used in the Two-Tom Lake area has proved to be successful. An initial airborne scintillometer survey highlighted the areas of potential, and a ground survey detailed the distribution of the anomaly-forming boulders. The boulders are varieties of syenite gneiss, some similar to those associated with the Mann # 1 deposit.

Bedrock outcrops are sparse within the survey area, although several are exposed in a stream associated with the southernmost train. Farther into the valley, the bouldery nature of the terrain masks all but a few outcrop occurrences. From the location of bedrock and the extent of the dispersal trains, it is apparent that the K-value, i.e., the distance between outcrop and the first occurrance of boulders derived from that outcrop, is probably less than 100 m, and that most (probably 90 percent) of the boulders were deposited within 600 m of their source. It is therefore likely that the bedrock source from which the mineralized boulders were derived is within a zone similar to, but larger than, that outlined by Westoll (1971), probably in the order of 200 m wide and greater than 1500 m long.

ACKNOWLEDGEMENTS

We wish to extend our thanks especially to the field crew Robert Smith and Morley Thompson who provided excellent service throughout the summer, as did Wayne Tuttle and Ken O'Quinn in handling our logistics from Goose Bay. Thanks also to Randy Miller, John McConnell and their crews who provided companionship during the summer. The manuscript

Table 1: Description of some rock types in the Two-Tom Lake area.

Sample Number	Rock Type	Grain Size	Color	Physical Characteristics	Total Counts Per Second
854951	Syenite gneiss	Medium	Gray, Brown	Pink felsic bands, foliated	5000 (boulders)/ 6000 (outcrop)
854954	Syenite gneiss	Medium	Brown	Black streaks of amphibole (Mann type)	10,000 (boulders)
854955	Volcanic(?) rock	Fine	Dark green	Massive, non-foliated	2600 (boulders)
854956	Syenite gneiss	Medium to Coarse	Light gray, Green	Moderately foliated	1000 (boulders)
854960	Syenite gneiss	Fine to Medium	Gray	Well developed gneissic foliation	4500 to 5000 (boulders)

was reviewed by Maryann Mihychuk, Byron Sparkes and Doug Vanderveer.

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QUATERNARY MAPPING/DRIFT PROSPECTING, MORAN HEIGHTS, LABRADOR

D. G. Vanderveer
Quaternary Geology Section

INTRODUCTION

Quaternary mapping at a detailed level commenced in 1984 at the request of Saarberg Interplan. Its objective was to define the source of uranium-bearing boulders on the company's Moran Heights property, which lies approximately 140 km north of Goose Bay, Labrador (Figure 1). Aside from airphoto-based surficial mapping (Fulton *et al.*, 1980), there has been little previous Quaternary work in the area.

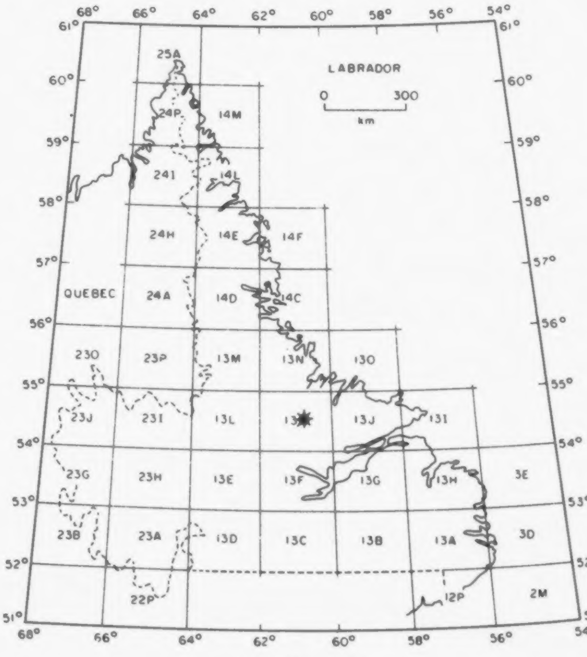


Figure 1: *Index Map, Moran Heights area.*

The site of investigation lies in a north-northeast-trending valley (at the northeast end of Moran Lake) that is underlain by arkosic sandstone and conglomerate of the Heggart Lake Formation (Ryan, 1979). The valley is bounded by a hillside that rises 160 m on the west side and consists predominently of mafic lava, breccia and siltstone of the Moran Lake Group. The hillside on the east is partly composed of rocks of the Heggart Lake Formation and rocks of the Moran Lake Group. Massive to foliated granitoid plutonic rocks underlie the northern part of the study area.

FIELD WORK

Summary of 1984 Results

As a result of field work in 1984, it was concluded that the mineralized boulders occurred in till (Vanderveer, 1985) and not in colluvium as had previously been assumed (Perry, 1980). In addition, two glacial flows were identified, a flow to the east-northeast and a later flow to the north. The later flow has been interpreted as being responsible for the construction of lateral moraines on both sides of the valley and a small moraine (possibly recessional) near the north end of the lake (Vanderveer, 1985).

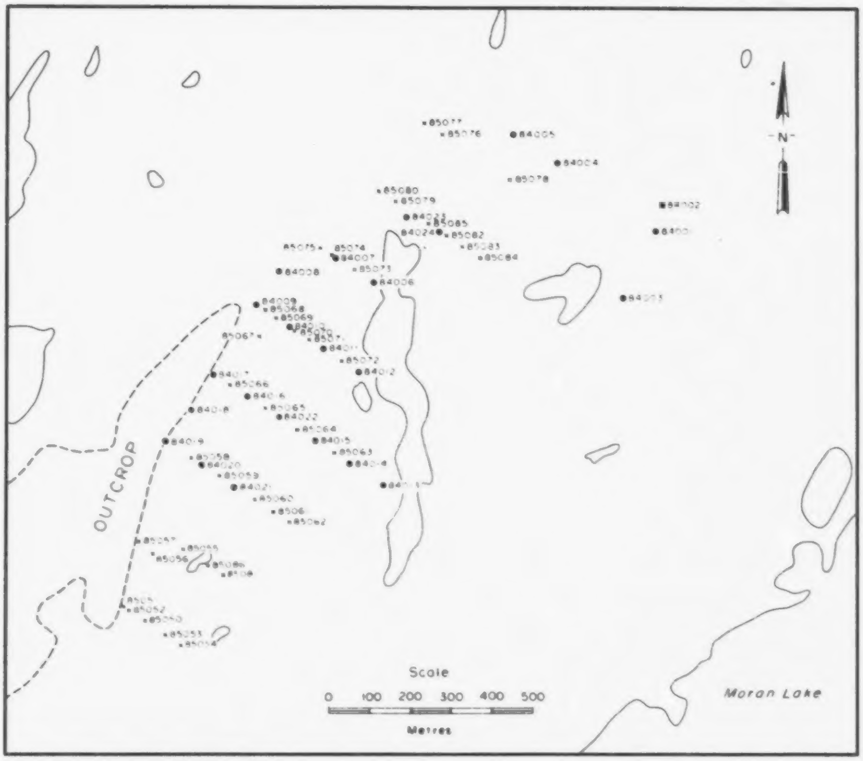
The 1984 till sample density (Figure 2) was sparse, but the preliminary unregressed results do identify a zone of anomalous geochemical values (ppm) for U (Figure 3), Co, Mo, and Pb (Figure 4).

These anomalies extend in both a down-ice and up-ice direction from the main boulder concentration at Moran Height and appear to be closely related to the northward glacial flow. The extension of the anomaly south (up-ice) of the main boulder field indicates either that the source area lies farther south than the boulders, or that there is more than one source area.

Field Program 1985

Field work this past summer involved the collection of additional till and pebble samples (for lithological analyses) within the area sampled in 1984 (to provide a sample density of one sample per 50 m along grid lines spaced 200 m apart). In addition, the sampling grid was extended toward the north and south (Figure 2). These traverses assisted in refining the location of the till deposits in the area. Through this approach, it was found that the moraine at the north end of the pond is not as extensive as previously assumed from an earlier airphoto analysis. The moraine is limited to the west side of the pond. The main ridge across the north end of this pond is bedrock controlled and has a thin mantle of glacial till.

It is expected that the results from the 1985 sampling program should refine the geochemical pattern of U and other elements in till, and define the southern limit of this dispersal pattern. The pebble lithology studies will be useful in



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84013
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85060
8506
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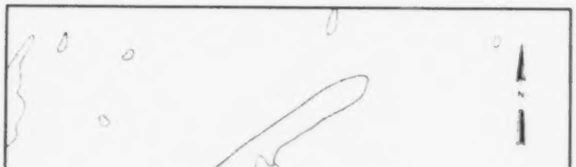
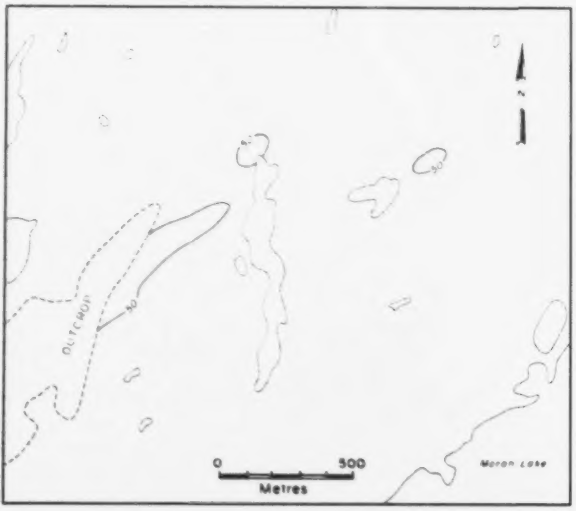
85055
85056
85086
8505
85052
85050
85053
85054
OUTCROP
Scale
0 100 200 300 400 500
Metres
N
Moran Lake

Figure 2: *Site locality map, 1984-85 field programs.*
• 84019 - Site 019 sampled in 1984
x 85060 - Site 060 sampled in 1985



30
40
30
OUTCROP
0
500
Metres
N
Moran Lake

Figure 3: *Distribution of U (ppm) in till for 1984 sites. These are raw values without any statistical treatment, e.g., no correction for elemental affinities.*



30
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OUTCROP
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Moran Lake

Figure 4: *Distribution of Pb (ppm) in till for 1984 sites. These are raw values without any statistical treatment, e.g., no correction for elemental affinities.*

defining probable source areas for the till and the mineralized clasts.

Future Plans

Plans include the following: a) completion of the till geochemical, pebble and grain size analyses, b) revision of the Quaternary map for the area, and c) preparation of a joint Newfoundland Department of Mines and Energy-Saarberg Interplan report which will summarize the following: (i) the history of exploration, (ii) current exploration activities, (iii) distribution of the glacial deposits and direction of transport, and (iv) the geochemical dispersal of the mineralization in soils and till.

ACKNOWLEDGEMENTS

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Note: Mineral Development Division file numbers are included in square brackets.

*Current Research (1986) Newfoundland Department of Mines and Energy,
Mineral Development Division, Report 86-1, pages 271-282*

QUATERNARY MAPPING AND EXPLORATION IN THE BELLBURNS MAP AREA (12 I/5 and 6) AND TRAPPER PROSPECT AREAS

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ABSTRACT

The Bellburns map area is located on the Northern Peninsula and hosts several zinc deposits, including the Trapper Prospect. Surficial deposits are divided into six major lithogenetic units: namely 1) bedrock, 2) glacial, 3) glaciolacustrine, 4) glaciofluvial, 5) marine, and 6) organics. Bedrock is best exposed along the coast and the Long Range escarpment. Glacial sediments have very limited exposure and are divided into lodgement and water-lain till facies. Glaciolacustrine sediments occur on the highlands in the central portion of the area, and are interpreted to have been deposited in a glacial lake produced by Laurentide ice from Labrador. Minor deposits of glaciofluvial gravel are found on the floors of the glacially scoured troughs that incise the Long Range escarpment. Marine sediments blanket the area to an elevation of 140 m.

Two glacial events are proposed, an earlier flow of Laurentide ice and a subsequent readvancement of Long Range ice; each event was followed by marine incursions.

Detailed Quaternary exploration was conducted in the Trapper Prospect area. Surficial sediments are water-lain and most of the boulders are transported. Mineralized float was most abundant 0.7 to 0.9 km northwest and west of the prospect, apparently related to the draining of the glacially dammed lake.

INTRODUCTION

During the 1985 field season, regional Quaternary mapping was conducted in the Bellburns (12I/5 and 6) map area, in support of detailed drift prospecting in the vicinity of the Trapper Prospect (Figure 1). The area was selected because it is known to host several mineral deposits, including the Daniel's Harbour zinc mine, and also because of the occurrence of numerous mineralized boulders. The aims of the study were: to define the surficial deposits in terms of their physical properties and spatial distribution; to identify glacial ice flow features; to study, in detail, the high grade mineralized boulders that are located west of the Trapper Prospect, and to determine their depositional environment and possible source area.

The study area extends eastward from the coast to the Long Range Mountains. Accessability was along the Northern Peninsula highway and the moderately extensive network of woods roads in the area. The field program included surficial mapping, soil profile sediment sampling, backhoe test pitting to establish stratigraphic relationships, and dithizone field testing for zinc.

Glacial History

Many researchers, e.g., Murray (1882), Daly (1921), Coleman (1926), Flint (1940), McClintock and Twenhofel (1940), Tanner (1940), Brookes (1969, 1970), Grant (1969a, b) and Prest (1970), have speculated on the glacial history of western Newfoundland. This interest stems from the controversy concerning the glacial history of insular Newfoundland. In particular, the question of whether the island was glaciated by the Labrador sector of the Laurentide ice sheet, or supported independent ice masses has not been completely resolved. For the Northern Peninsula, Grant (1969a, b, 1970, 1972a, b, 1973a, b, 1974, 1975) has proposed the following four phases in the glacial sequence based on regional surficial investigations:

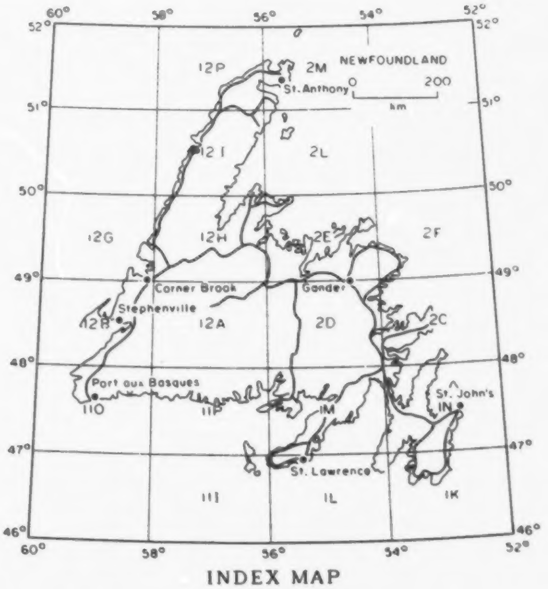


Figure 1: *Location map of Bellburns map area.*

a) During the Wisconsin, Laurentide ice advanced southward from Labrador, impinging onto the lowland areas of the Northern Peninsula and up to 300 m above sea level on the flanks of the Long Range Mountains. The limit of the southern extent of this ice is placed at St. John Bay, north of Port au Choix.

b) Subsequent to retreat, which was mainly by ice calving, marine levels reached a maximum of approximately 90 m higher than present day sea levels.

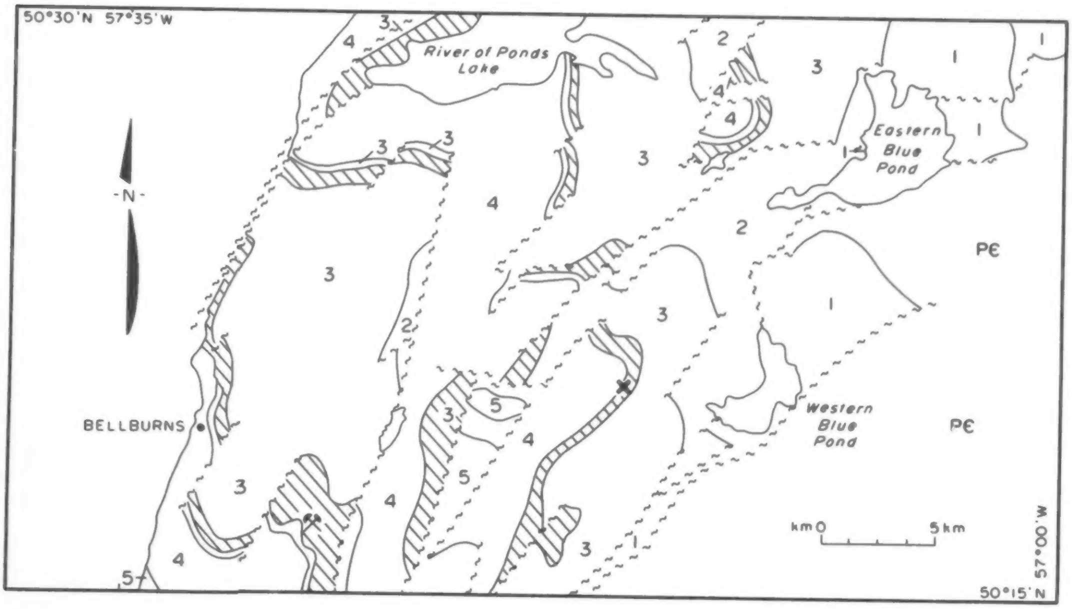
c) Readvance of Long Range ice during the Late Wisconsin to the lowlands, including 20 km beyond the present coastline.

d) Finally, retreat of the Long Range piedmont glaciers by ice calving into deep marine water.

Bedrock Geology

The Long Range Mountains are primarily composed of Grenvillian gneisses and granites. Overlying the Precambrian basement (Figure 1) are fault-bounded Cambrian rocks of the Labrador Group (Knight, 1977, 1978, 1980, 1985; Knight and Boyce, 1984). Unit 1 consists of the Bradore Formation, a red arkosic sandstone; the Forteau Formation, composed of pink, crystalline dolomite and gray shaly fossiliferous limestone, black shales and oolitic limestones; and the Hawke Bay Formation, which comprises white quartz-rich sandstone.

The Port au Port Group (Unit 2) comprises the Petit Jardin and March Point formations of middle to late Cambrian age. The March Point Formation has very limited exposure in the study area, and is composed of dark-gray shales and yellow weathering gray dolostones. The Petit Jardin Formation is much more extensive and consists primarily of stromatolitic, wavy laminated, buff weathering dolostones.



LEGEND

ORDOVICIAN

5 Goose Tickle Formation and unnamed rocks.
4 Table Head Group: Table Cove, Black Cove, Table Point formations.
3 St. George Group: Watts Bight, Boat Harbour, Catoche, Aguathuna formations.

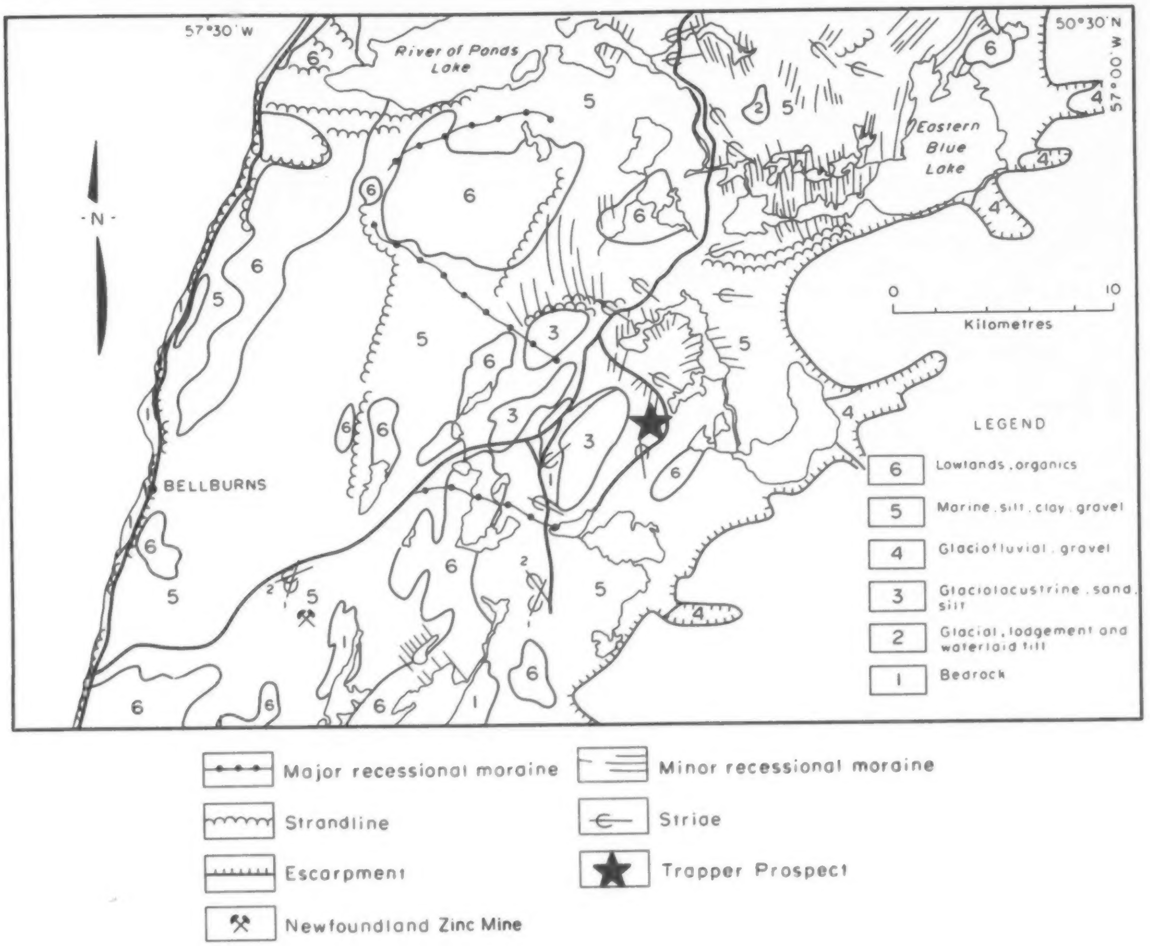
CAMBRIAN

2 Port au Port Group: March Point, Petit Jardin formations.
1 Labrador Group: Bradore, Forteau, Hawke Bay formations.

PRECAMBRIAN

Grenville basement: granite and granite gneiss.

Figure 2: *Generalized bedrock geology of the Bellburns (12I/6 and 5) map area (modified from Knight 1985). Cross-hatched areas represent zones of potential mineralization in diagenetic dolostone.*


57°30' W
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River of Ponds Lake
Eastern Blue Lake
BELLBURNS
N
0
10
Kilometres
LEGEND
6 Lowlands, organics
5 Marine, silt, clay, gravel
4 Glaciofluvial, gravel
3 Glaciolacustrine, sand, silt
2 Glacial, lodgement and waterlaid till
1 Bedrock
Major recessional moraine
Minor recessional moraine
Strandline
Striae
Escarpment
Trapper Prospect
Newfoundland Zinc Mine

Figure 3: *Surficial geology of the Bellburns study area.*

The Lower Ordovician St. George Group (Unit 3) is divided into the Watts Bight, Boat Harbour, Catoche and Aguathuna formations. The basal Watts Bight Formation is dark gray to black, fine to medium grained, mottled, cherty dolostone. Interbedded limestones, dolostones, shaly limestones and diagenetic dolostones characterize the poorly exposed Boat Harbour Formation. The distinctive Catoche Formation is composed of well bedded, gray limestone containing extensive dolomitic burrow-mottling. In the upper portion, the limestone is replaced by light to dark-gray, vuggy, diagenetic dolostone, commonly referred to as psuedobreccia, which hosts zinc mineralization. Overlying the Catoche Formation are the microcrystalline dolostones of the Aguathuna Formation.

The Middle Ordovician Table Head Group (Unit 4) comprises the Table Point Formation, a blue-gray, fossiliferous, well bedded limestone and laminated dolostone; the Table Cove Formation, a thinly bedded, nodular, lime mudstone containing shale interbeds; and black shales of the Black Cove Formation. Interbedded green sandstones and black shales define the Goose Tickle Formation (Unit 5), a wedge-shaped unit that extends from Brian's Pond northward to the central part of the study area.

REGIONAL QUATERNARY MAPPING

Regional Quaternary work at 1:50,000 scale was conducted over the study area and involved surficial mapping, determining ice flow directions and establishing stratigraphic relationships.

Coverage of the study area was obtained by road, helicopter and boat traverses. During the regional mapping program, 164 suites were visited and 350 samples collected. At each location, landform information, such as landform type, drainage and vegetation type, was recorded. As well as landform information, detailed sedimentological discriptions on deposit type, soil horizon, texture, compaction, structure, fissility, sorting and nature of the contact with other units were noted. Matrix samples (material less than 4 mm), usually from the C horizon, were collected from each unit encountered. Soil profile samples of the B, BC and C horizons were taken consistently over the study area, to establish soil-dependant geochemical trends. Where the sediment contained

Table 1. Indicator pebble classification for the Bellburns study area.

Rock Type Code No.	Description	Map Unit	Formation
05	Sandstone	5	Goose Tickle
95	Very light-gray limestone, clacite spar	4	Table Point
90	Dark-gray, fossiliferous limestone	4(3)	Table Point (Catoche)
96	Cherty limestone, chert	3(4)	Catoche (Table Point)
89	Dark-gray limestone containing dolomite seams	3	Catoche
98	Cherty dolostone	3	Catoche (Aguathuna)
94	Laminated dolostone	3	Aguathuna (Boat Harbour)
97	Diagenetic, dark, vuggy dolostone	3d,3	Catoche (Watts Bight)
93	White, sparry, veiny dolostone	3d	Catoche
92	Pseudobreccia	3d	Catoche
99	Mineralized pseudobreccia	3d	Catoche
91	White, vuggy, microcrystaline dolostone	2(3)	Petit Jardin (Aguathuna)
12	Oolitic limestone with brown weathering rind	1	Forteau
01	Gray to black shale	1	Forteau (Goose Tickle)
32	White quartzite	1	Hawke Bay
22	Intrusives	PE	N/A
50	Weathered pebbles	N/A	N/A

a substantial number of pebble-size clasts, a population of approximately 100 was collected for lithological identification. Boulders were also identified and described, including observations on the degree of rounding, color, grain size, and the type of mineralization. Generally, 10 to 20 boulders were examined at each locality and samples were collected from mineralized float.

Specific indicator rock types, which included representative samples from each major rock unit (Figure 2; Table 1), were identified for the purpose of aiding in the determination of transport directions. The rock types selected represent facies within a rock unit that are unique to that unit, or can be correlated with the rock unit with a reasonable degree of certainty. Pebble collections from surficial sediments were then classified into the selected lithological catagories.

Overall, the area is generally a gently undulating carbonate terrane, locally exhibiting karstic features. It is covered by extensive areas of bog, particularly along the coast. Marine sediments, commonly fossiliferous, dominate the surficial deposits, and there is evidence of marine reworking of the other surficial deposits across most of the area (Figure 3).

Major glacial features in the study area include three large moraines, aligned perpendicular to the coast, located in the central region of the study area. In addition, there are well developed cross-valley moraines associated with the major valleys extending from the Long Range Mountains. These moraines have minor relief, are closely and regularly spaced, and can be seen clearly on aerial photographs. The cross-valley moraines extend approximately 10 km from the escarpment and are related to ice that originated from the Long Range Mountains.

The surficial geology has been divided into six mappable units: bedrock, glacial sediments (lodgement and water-lain till facies), glaciolacustrine deposits, glaciofluvial deposits, marine deposits, and organics.

Bedrock (Unit 1)

The best bedrock exposures occur along most of the coastline and on the escarpment and highlands of the Long Range Mountains. Topographic highs are generally structurally controlled, and bedrock is generally exposed along the flanks. Isolated bedrock outcrops are also found in lowland areas, swamps and bogs. However, there is usually 1 to 2 m of surficial sediments overlying bedrock.

Natural bedrock exposures are rounded and weathered, and nearly all evidence of glacial grooves or striations is obliterated. Fresh bedrock surfaces, exposed along logging roads, provide fresh unweathered outcrops where polished and striated surfaces may be observed.

Glacial Sediments (Unit 2)

Glacial sediments have limited exposure (less than 10 percent) in the study area, however, they were encountered in numerous hand-dug and backhoe pits. Two facies were identified:

a) An unsorted, unstratified, brownish-gray, overconsolidated diamicton is interpreted as lodgement till (Plate 1). This till facies contains subrounded to subangular clasts, which are commonly striated and of local provenance. The overall structure is compact, with an average of 46.6 percent silt and clay content. This facies is assumed to have been deposited by ice from the Long Range Mountains, and is the latest glacial event that occurred during the Late Wisconsin.

b) A more common facies is an underconsolidated, poorly sorted, sandy diamicton. This facies locally contains evidence of sorting, e.g. sand lenses, and is interpreted as representing a water-lain till, deposited at the ice-water interface. Difficulty was

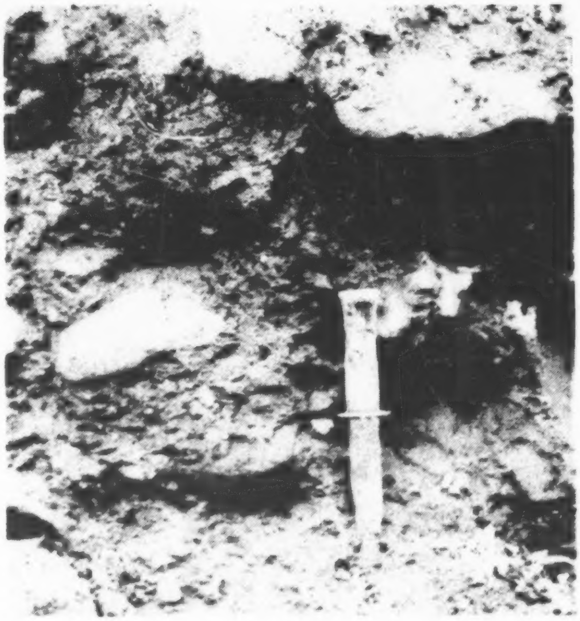


Plate 1: *Overconsolidated, fissile, unsorted, unstratified, silty diamicton containing subrounded to subangular clasts.*

encountered in distinguishing this facies from poorly sorted marine sediments. Generally, if the sediment exhibits a very wide range of grain size, and contains no marine fauna, it is defined as water-lain till. However, there is a gradation from ice to marine environments, including ice-rafted sediments, which make the determination subjective.

Glaciolacustrine Sediments (Unit 3)

Moderate to well sorted, locally stratifical, silty sand to sand deposits were identified on three highland areas near the Trapper Prospect in the central part of the map area. These sediments occur above the known marine limit (Grant, 1972c) up to 200 m above present sea level. Topography of the area is gently rolling to flat. Sediments vary in thickness from 40 to 90 cm and grade into a poorly sorted, pebbly diamicton. The well sorted sands appear to have been water-lain. This, and the lack of any marine evidence, suggests the sediments were deposited in a glacially dammed lake.

Glaciofluvial Deposits (Unit 4)

The glacially scoured troughs that cut the face of the Long Range Mountains are generally floored by glaciofluvial and fluvial sediments. Five meters of well sorted, well stratified, sandy pebble gravel occur in a stream cut in the valley that enters Eastern Blue Pond. Other glaciofluvial deposits were identified between the central highlands west of the Trapper Prospect and southwest of Big Northeast Pond (Plate 2). These deposits probably represent abandoned drainage ways.

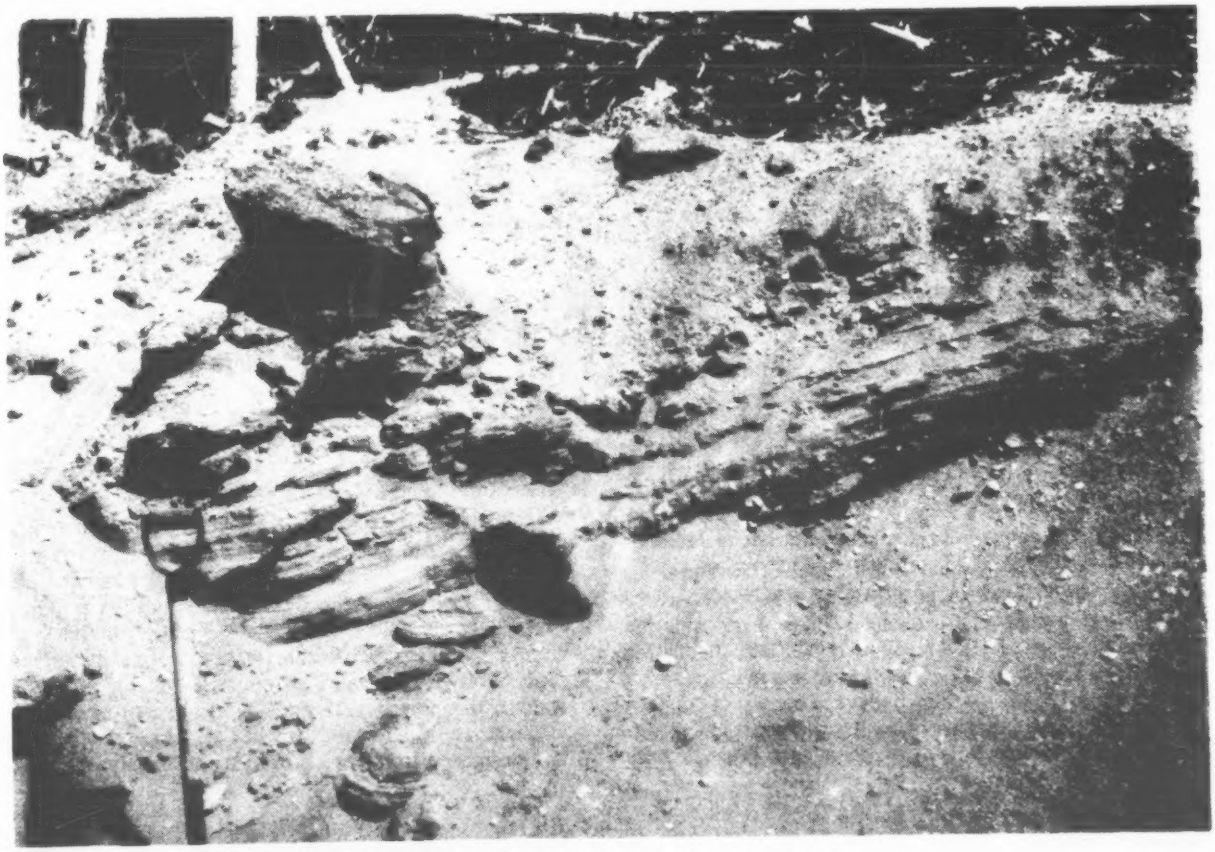


Plate 2: *Well stratified, well sorted pebbly sand in glaciofluvial sediments (Unit 4).*

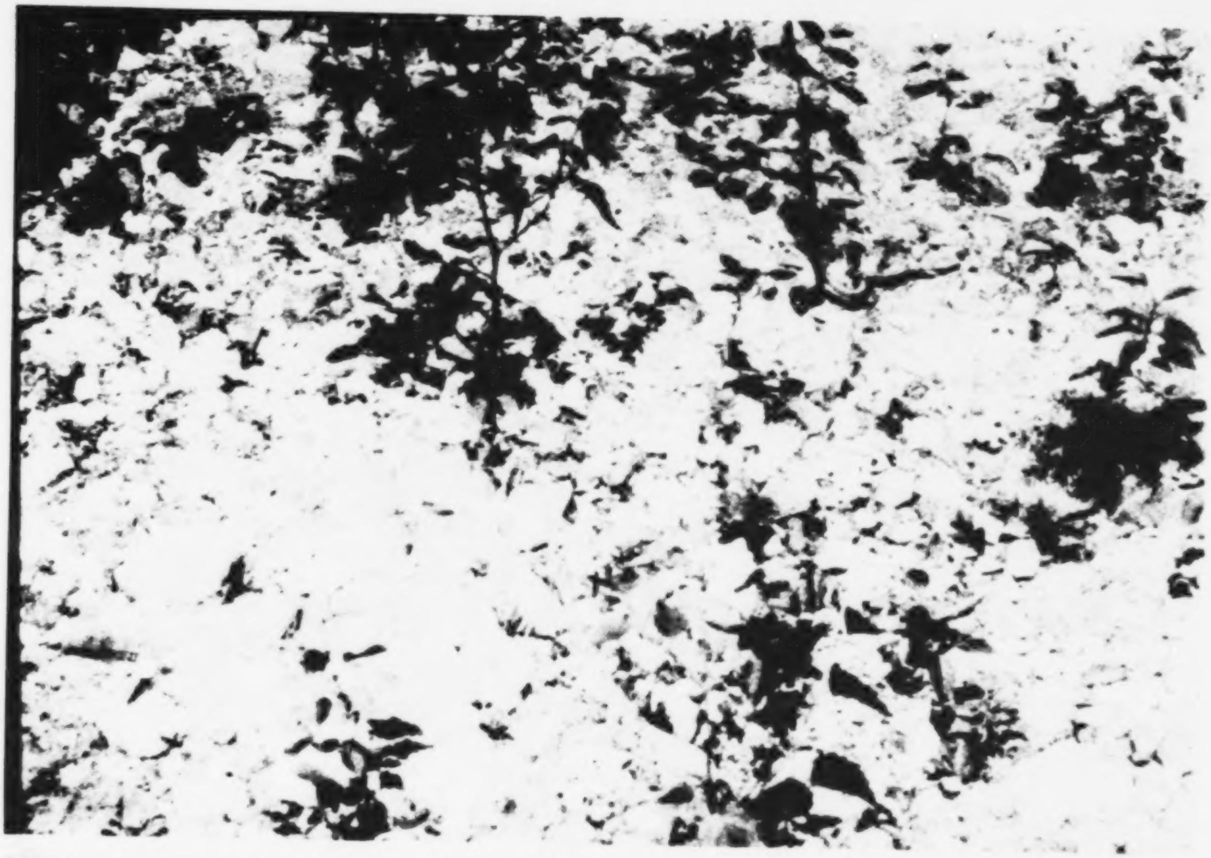


Plate 3: *Quaternary marine shell bed in abandoned beach deposit.*

Marine Sediments (Unit 5)

Marine sediments make up the majority of the surficial sediments in the study area, extending from the coast to the base of the Long Range Mountains. The sediments exhibit enormous variability over short distances. Grant (1975) also found it difficult to differentiate the marine facies from glacial deposits. Generally marine sediments are quite coarse grained, contain a large pebble fraction, and have a silty sandy matrix (32.09 percent silt and clay). These sediments are well to poorly sorted and are generally massive. The plutonic component of the pebble fraction in the marine sediments appears to be enriched compared to the tills. At a locality 1 km north of the Daniel's Harbour mine site, the clasts averaged 21 percent intrusives compared to 10 percent in the underlying lodgement till.

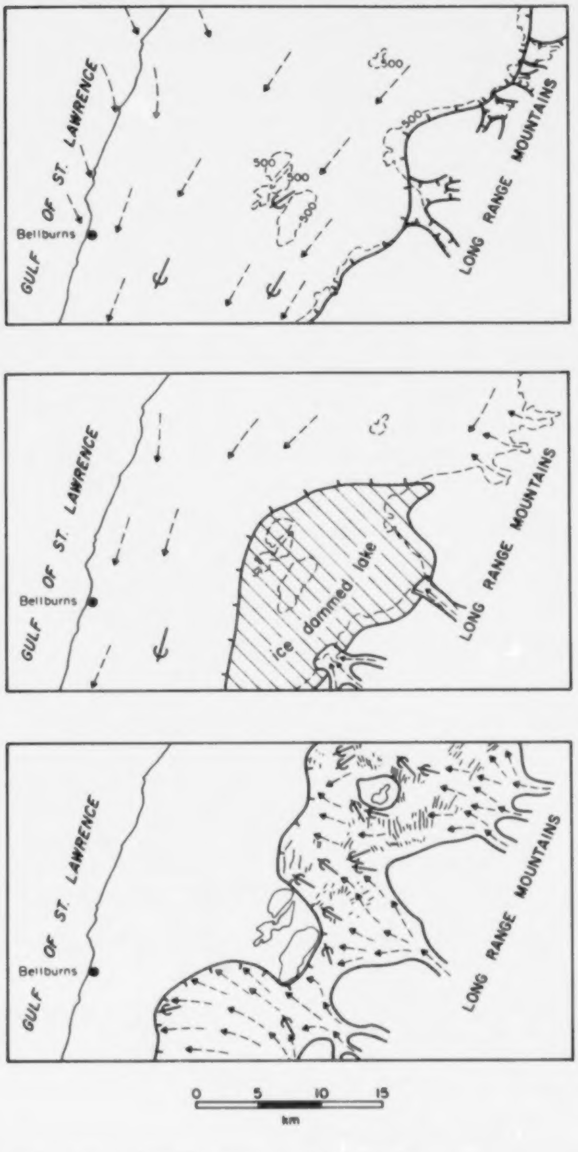
The sediments commonly contain shell debris and shells were collected from a total of 17 localities, 16 of which were not previously sampled. Shell debris (Plate 3) was collected up to an elevation of 138.5 m, 38 m higher than the marine limit defined by Grant (1972c). Buried marine sediments were encountered 1.2 km south of Bellburns Pond in a backhoe trench. Here, fossiliferous pebbly silt is overlain by silty, overconsolidated, lodgement till, which in turn is overlain by moderately sorted underconsolidated marine sediments. This indicates a marine incursion prior to the last glacial event and a second marine incursion following deglaciation. Marine fossils in the lowest unit were collected for dating.

Organics (Unit 6)

Extensive bogs and marshlands are situated along the coast, south of River of Ponds Lake, and northward from Brian's Pond to Cobo's Pond. Although not as continuous, bogs are common in the coastal lowland plains. Organic sediments usually overlie nearshore marine deposits or bedrock.

Glacial Flow Patterns

Two glacial ice flow patterns were identified in the study area. Evidence for the two events includes striae and moraine systems (Figure 3). Striae were observed at ten localities and two glacial ice flow directions were determined. The earliest flow, to the southwest at 210, was generally parallel to the coastline. Straie related to this flow event occur 0.6 km northeast of Mike Lake and 2 km southwest of Big North East Pond. The most prevalent and dominant set of striae is the western trend (250 to 290), related to the last glacial event that originated from the Long Range Mountains.



Phase I. Labrador ice being deflected by the Long Range Mountains, down the Northern Peninsula.

Phase II. During deglaciation, a glacially dammed lake is created between the ice margin, which is being topographically controlled, and the Long Range escarpment. There is a significant amount of calving from the valley glaciers into the lake. This is considered to be a relatively short lived event.

Phase III. Late Wisconsin readvance of the Long Range valley glaciers onto the coastal plain. Flow is topographically controlled by relief on the plain. This is considered to have been a relatively minor event.

Figure 4: *Proposed model of deposition.*

Two moraine systems occur in the area—cross-valley moraines that are relatively small and much larger moraines orientated perpendicular to the coastline. The cross-valley moraines are related to glaciers that originated in the Long Range Mountains. The origin of the other larger moraines is equivocal. They either represent recessional moraines of ice (presumably Labrador ice) that retreated northward up the peninsula, or they are interlobate moraines produced by coalescing glaciers from the Long Range Mountains (Grant, 1969b).

Evidence as to the origin of these moraines is generally lacking and any interpretation is speculative. However, if the cross-valley moraines are taken to represent the extent of the ice from the Long Range Mountains, then the two types of moraines do not appear to be related to the same glacial event. The large moraines and the southwest straie could suggest that there was an earlier glacial event with ice direction parallel to the coast, i.e., the Laurentide ice sheet from Labrador crossed over the Strait of Belle Isle and was channeled down the coastline of the Northern Peninsula.

Model of Deposition

A tentative model of deposition is proposed, which attempts to include all the observed information from the study area (Figure 4). There are several characteristics of the surficial geology which must be considered:

1) Evidence of ice flow indicates two flow directions, an early direction parallel to the Northern Peninsula (210), followed by ice advancing toward the coast (250-290) from the Long Range Mountains.
2) Buried marine sediments, 1 km northeast of Mike Lake, indicate marine events prior to the last glacial event.
3) Distinctive and abundant cross-valley moraines can be traced from near the foot of the Long Range Mountains westward. The distribution of these moraines is topographically controlled; thus it appears that the ice was relatively thin and of limited extent.
4) Marine limit in the area appears to have been 140 to 150 m above present day sea level, and marine sediments and erosion have masked or subdued most of the glacial features in the area.
5) Water-lain sediments occur above known marine limits in the central portion of the study area.

When considering the information available, it appears there are two identifiable glacial events, an early flow down the peninsula, then an ice advance from the Long Range Mountains. Each event was followed by marine incursion. It appears that the earlier glacial event was probably Laurentide ice from Labrador that was diverted southward by the Long Range Mountains. As the ice retreated, probably by calving into marine waters, large moraines were deposited perpendicular to the coast. Some time later, ice readvanced from the valley glaciers of the Long Range Mountans, depositing cross-valley moraines. This readvance was realtively minor, ice being quite thin and of limited extent. Marine levels following deglaciation mask virtually all of the topography.

The water-lain silts above known marine limits must have been deposited in a glacially dammed lake. Considering the relatively local extent of the Long Range ice advance, it seems unlikely that the glaciers could have coalesced west of the central highlands. Therefore, it is assumed that the earlier Labradorian ice formed a glacially dammed lake during retreat, where the silts and sands were deposited (phase II of Figure 4).

QUATERNARY EXPLORATION PROGRAM

Exploration in 1963 by Pegg (1964) for Leitch Gold Mines Ltd. led to the discovery of the Daniel's Harbour zinc deposit. During the same program, high- and low-grade zinc float of unknown origin was discovered approximately 30 km northeast of the Daniel's Harbour deposit. This became known as the Trapper Prospect. Tecam Exploration Ltd. (1976) and Lane (1980) conducted follow-up exploration with geological mapping, diamond drilling and soil geochemistry. Mineralization exposed at the bedrock surface was determined by drilling to be a 0.3 m thick bed of sphalerite-rich pseudobreccia. The mineralized float previously identified, which trends westward from the mineralized bedrock, was assumed to be glacially deposited. The boulders are considered to have originated from the mineralized outcrop, and represent the eroded remains of the deposit. No other sources were considered.

A detailed Quaternary exploration program was conducted in the Trapper Prospect area. Lines were run by chain and compass, with station sites every 250 m. Hand-dug pits were excavated to an average depth of 70 to 80 cm, and sediment matrix and clast samples were collected from the C horizon. Soil profile samples were also collected at several stations. Boulders were identified and sampled if they contained mineralization. A skidder-mounted backhoe was also employed in the Trapper Prospect area to provide better exposure of sediments and to establish stratigraphic relationships. A total of 18 backhoe pits were dug, and 77 samples were collected.

The study area includes the Trapper Prospect and extends across the topographic high 1 km north of Little North East Pond. Mineralized bedrock occurs at the base of the highland, whereas the mineralized float is primarily found 60 m higher on the eastern flanks of a prominent ridge (Figure 5). Float had been identified (Pegg, 1964) from the bottom of this ridge, westward for 2 km. During the past field season, several additional mineralized boulders were located and 25 were sampled. The majority of the mineralized boulders are concentrated on the flank of the ridge, covering an area 1 km wide that extends 0.5 km west of the Trapper Prospect.

During detailed mapping five surficial units were identified (Figure 5). Unit 1 consists of sand, pebbly sand and gravel deposits below the marine limit. These sediments are well oxidized in the B horizon and are generally well to moderately well sorted. Genetically, they appear to be related to marine deposition, although no marine shells were found in the area. The Trapper Prospect is located in a low-lying area within this marine unit. Surficial sediments over the prospect are thin (less than 10 cm) and consist of a fine sand with a high organic content.

Unit 2 comprises lowland bog and swampy areas. A large area of marshland extends along the base of the hill on the eastern side. Sediments are organic, and range in thickness from 20 cm to 1 m.

Along the eastern flank of the hill, an area of boulder concentration was identified (Unit 3). Pavements of very well rounded psuedobreccia boulders (Plate 4), many of them mineralized, occur 0.1 km northwest of the Trapper Prospect. Although the majority of boulders are rounded, several very large (diameter greater than 1 m), angular to subangular, mineralized boulders occur 0.9 km west of the prospect. Well sorted sand and pebbly sand are usually developed between and beneath the boulders.

Fine sand and silts containing minor pebbles (Unit 4) occur above a known marine limit of 140 m. This unit was found in the central portion of the area and covered the highest elevations. Generally, the sediments are well sorted, moderately compact and grade into a very poorly sorted, sandy, pebbly diamicton. The silt and sand vary in thickness from 0.30 to 0.90 m with an average of 0.70 m. Since the sediments

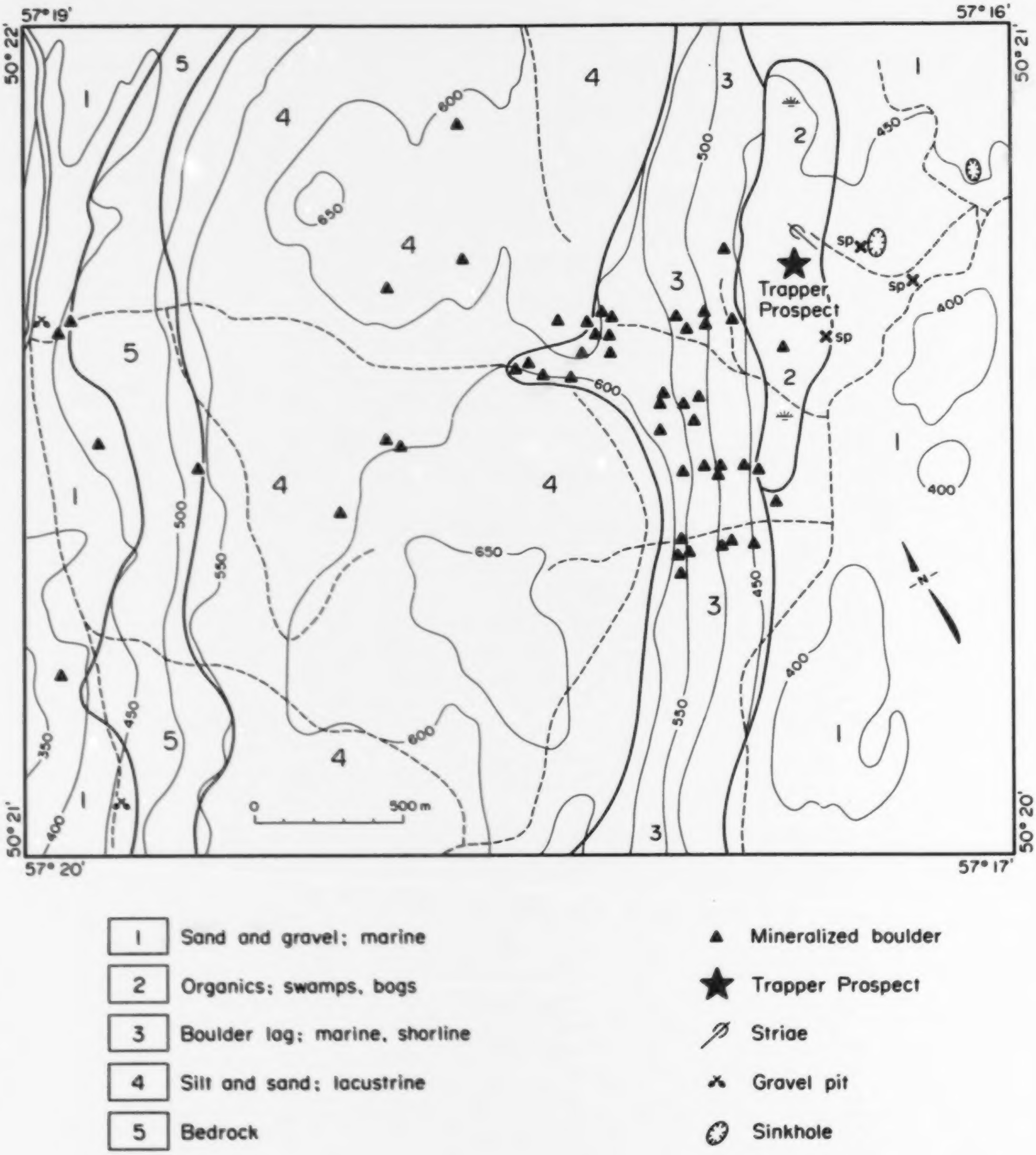

57° 19'
57° 16'
50° 22'
50° 21'
50° 21'
50° 20'
57° 20'
57° 17'
Trapper Prospect
sp
600
650
500
550
450
400
350
0
500 m
N
1 Sand and gravel; marine
2 Organics; swamps, bogs
3 Boulder lag; marine, shorline
4 Silt and sand; lacustrine
5 Bedrock
Mineralized boulder
Trapper Prospect
Striae
Gravel pit
Sinkhole

Figure 5: *Surficial deposits and mineralized boulders in the Trapper Prospect study area.*

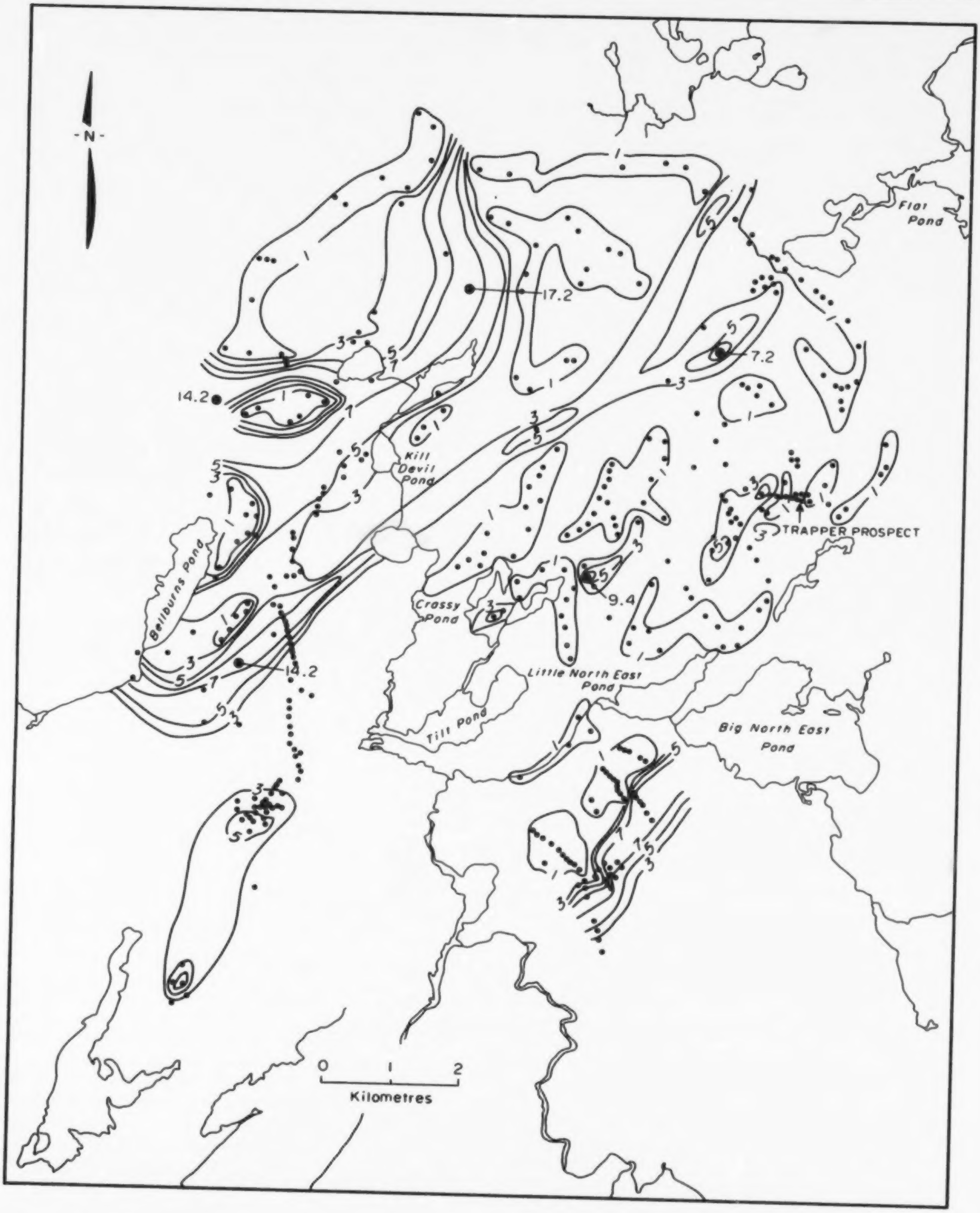

N
Flat Pond
17.2
7.2
14.2
Kill Devil Pond
Bellburns Pond
TRAPPER PROSPECT
Crassy Pond
9.4
14.2
Little North East Pond
Till Pond
Big North East Pond
0
1
2
Kilometres

Figure 6: *Drift thicknesses in the Bellburns Pond - Trapper Prospect area; spot thicknesses are included.*

Plate 4: *Very well rounded pseudobreccia boulders; many are mineralized in the Trapper Prospect area.*

are water-lain and non-marine, and grade into a diamicton, they are interpreted as glaciolacustrine, and grade into a flow or water-lain till.

Bedrock (Unit 5) is exposed along the western side of the highland, covered in places by a thin veneer of sand.

Drift Thickness

Overburden thicknesses were compiled for the Trapper Prospect area from drillhole information in assessment files (Figure 6). To correct for casing, 1 m was subtracted from the recorded thickness.

Surficial sediments vary from thin patches of marine sediments of less than 10 cm to areas of buried valleys with over 17.2 m of material. Two major buried-valley systems were identified in the preliminary assessment of drillhole data in the Trapper Prospect area. The largest system has a maximum sediment thickness of 17.2 m, with an average thickness of greater than 7 m along its entire traced length. The second system is quite linear and appears to mark the trace of a fault zone; the greatest sediment thickness occurs near Bellburns Pond.

Future Research

Sediment geochemistry and grain size analyses of the samples are ongoing. The use of the various sediments will be assessed in terms of an exploration medium. Mineralized boulders will be analyzed and the type of mineralization will be compared to the mineralization at the Trapper Prospect, in an attempt to determine the source of the boulders.

ACKNOWLEDGEMENTS

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SURFICIAL AND GLACIAL MAPPING - PETER SNOUT (11P/13) AND KING GEORGE IV LAKE (12A/4) MAP AREAS, SOUTHWESTERN NEWFOUNDLAND

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Quaternary Geology Section

ABSTRACT

Mapping was conducted during 1985 in the King George IV Lake (12A/4) and Peter Snout (11P/13) map areas of southwestern Newfoundland. A till sampling program was completed on a 2 x 2 km grid spacing. Samples were collected from the C soil horizon from lodgement and meltout till facies. Pebble lithologies were determined and referenced to bedrock map units. These data will be used to determine till geology and to aid in the interpretation of ice flow directions and transport distances. Grain size analyses will be used to aid in the interpretation of the till geochemistry and to provide information on textural variations between till types and landforms. A ground verified landform classification map was completed using 1:50,000 black and white airphotos. Ice flow over both map areas is predominantly to the south, although a westward flow of ice in the northwest corner of the King George IV Lake map area may represent a response to the east-west structural grain and regional topographic slope.

INTRODUCTION

During the 1985 field season, Quaternary mapping was conducted in the Peter Snout (11P/13) and King George IV Lake (12A/4) map areas (Figure 1). This project is a continuation of the provincially funded Surficial and Glacial Mapping Program, designed to provide information on glacial geology and till geochemistry as an aid to exploration in areas of mineral potential and/or exploration activity. The area has limited access, except for the Burgeo road (Route 480) which crosses the eastern part of both map areas. Field work started in early June and continued until late August.

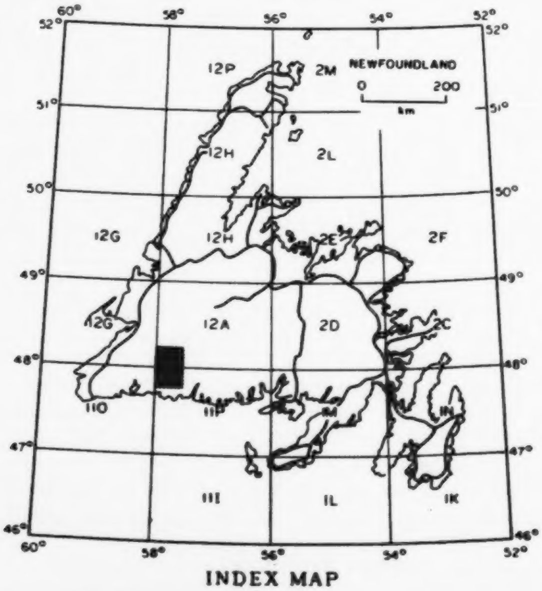

Figure 1: *Location of study area.*

The only published surficial geology map for the Peter Snout area (Grant, 1974) outlines the major depositional features (drumlins, ramps, etc.) and indicates a ubiquitous southward ice flow. There is no previously published map or report on the surficial geology of the King George IV map area.

PHYSIOGRAPHY

King George IV Lake

Most of the King George IV Lake map area is a barren, hummocky upland with an elevation of 350 to 400 m. High hills stand above this level to a maximum height of 552 m. Three major river systems, the Lloyds, Victoria, and Burnt Pond rivers, drain toward the northwest. The topographic morphology and main drainage pattern predominantly reflect the bedrock structures, although many of the smaller lakes and ponds show no discernible geological control. Some ponds, particularly in the area east of Rocky Ridge Pond (Figure 2), seem to reflect southward ice flow.

Peter Snout

The Peter Snout map area is characterized by large areas of barren plateau with an average elevation of 350 m. Numerous peaks over 500 m constitute part of the Blue Hills of Couteau in the northwestern part of the map area. Drainage is toward the south via the Grandy Brook system, and an unnamed brook which flows into Connaire Bay east of Burgeo. This drainage pattern is transverse to the regional geologic structure and may be controlled by cross-faults.

GEOLOGICAL SETTING

The King George IV Lake (12A/4) and Peter Snout (11P/13) map areas lie within the southern end of the Paleozoic Central Mobile Belt (Kean, 1983). Both areas contain elements of the Dunnage Zone, and the Peter Snout area also

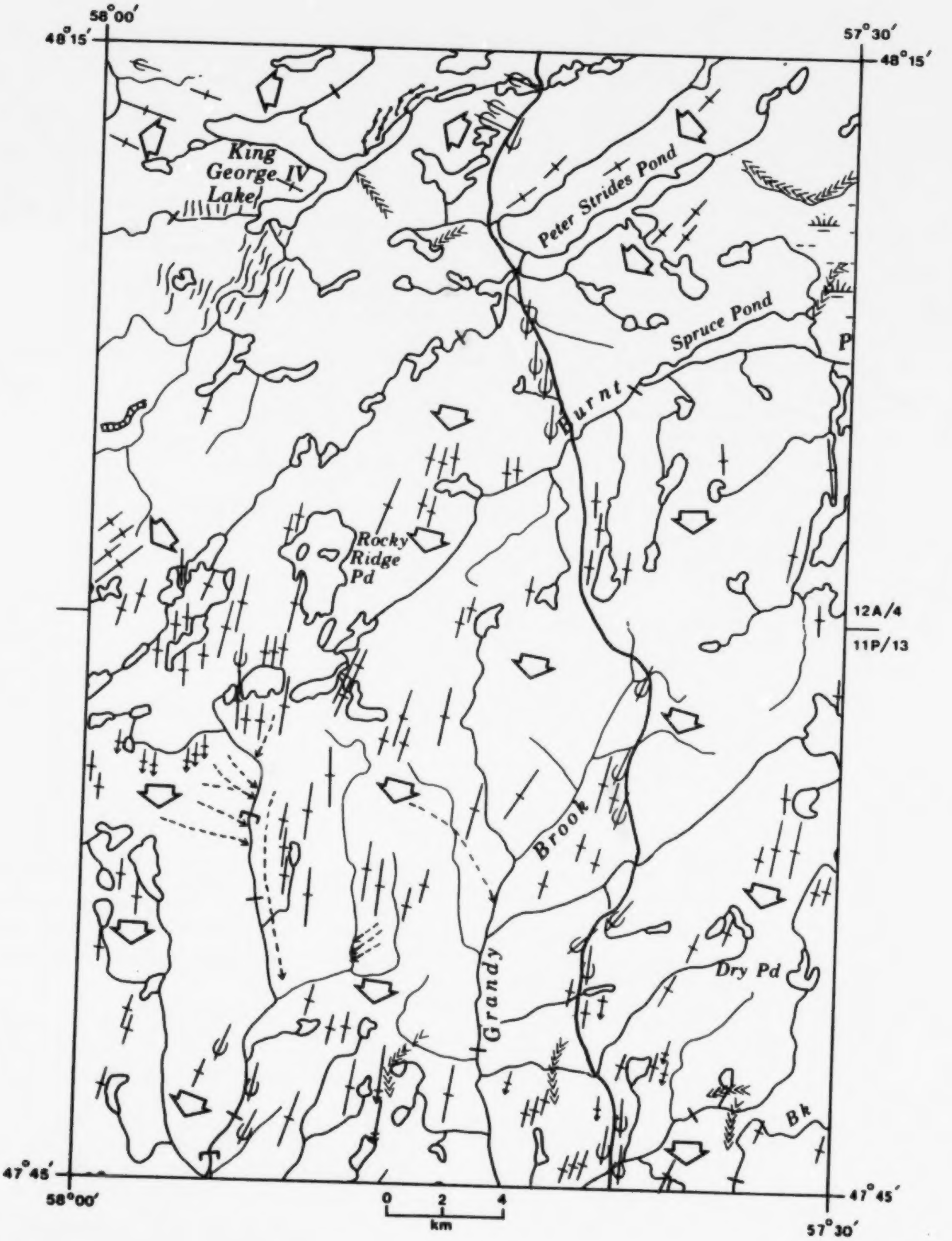
58°00′
48°15′
57°30′
48°15′
King George IV Lake
Peter Strides Pond
Spruce Pond
P
Burnt
Rocky Ridge Pd
12A/4
11P/13
Brook
Grandy
Dry Pd
Bk
47°45′
58°00′
0
2
4
km
47°45′
57°30′

Figure 2: *Regional ice flow features in the Peter Snout (11P/13) and King George IV Lake (12A/4) map areas.*

SYMBOLS

»»» Esker, crevasse filling.

⇢ Abandoned channel of former meltwater stream.

⇨ Direction of regional ice flows.

Longitudinal ice-flow features

—+— Drumlin, drumlinoid, fluting.

+→ Crag-and-tail hill.

—+→ Till ramp.

—∋ Striation.

Transverse ice-flow features

〰 Crestline of prominent moraine.

//// Ribbed moraine, DeGeer moraine, minor moraine.

has elements of the Gander Zone. The oldest units consist of ophiolitic rocks overlain by an island-arc sequence. These are unconformably overlain by fluviatile sedimentary and subaerial volcanic rocks that have a northeast-southwest trend in the northern area and an east-west trend in the south. Intrusive rocks range from Silurian to Carboniferous in age. The older intrusives are concordant with the structural trends, and the younger ones cross-cut them. The faults trend northeast-southwest in the north and east-west in the south. The rocks vary from undeformed to polydeformed and the grade of metamorphism varies from subgreenschist facies to amphibolite facies (Kean, 1983; O'Brien, 1983).

FIELD PROGRAM

Six hundred and six samples were collected from shallow (50 to 75 cm) hand-dug pits, on an approximate 2 x 2 km grid spacing. Ninty percent of these samples were taken from the C soil horizon, and the remainder were from either the B horizon or the B-C transitional zone. Three hundred and six samples were taken from the lodgement till facies, two hundred and forty-six were taken from the sub-glacial meltout facies, and the remainder were taken from esker or glaciofluvial deposits. A representative pebble fraction (16 to 32 mm) was obtained at approximately 400 sites, and the pebble lithologies were determined and referenced to a bedrock map unit where possible. A landform classification map has been completed for both map areas using 1:50,000 scale black and white airphotos. This landform interpretation was extensively ground verified during the course of field work and was used for determining ice flow directions, possible ice margins, and the distribution of surficial sediments.

DATA ANALYSES

The silt to clay size fraction (minus 64 micron) of all till samples will be analysed for Cu, Pb, Zn, Co, Ni, Ag, Mn, Fe, Mo, U, W and Au. The pebble lithology data will be used to produce a map of till geology, and used as an aid in the interpretation of ice flow directions, transport distance, and the pattern of glacial dispersal as determined from till geochemistry. Grain size analyses of the till matrix, employing a wet-sieving technique and a fine particle analyser (Coulter Counter), will be conducted to determine textural differences that occur both regionally and locally. This data will also be used as a variable to interpret the till geochemistry data.

GLACIAL FLOW

Ice flow in the Peter Snout map area (Figure 2) was generally to the south (180 to 210). Numerous drumlins, till ramps, striae, and crag and tail hills, scattered across the whole map area, are good indicators of this ice movement. Ice flow appears to have been controlled by the underlying bedrock topography, e.g., flow generally parallels Grandy's Brook. The orientation of eskers indicates that retreat of the ice was parallel to ice flow. Meltwater channels appear to indicate that glaciers retreated into some of the highland areas in the north-central part of the map area.

In the King George IV Lake map area, ice flow is more varied (Figure 2), having moved: (a) to the southwest, parallel to Peter Strides Pond in the northeast corner of the map area, (b) south in the central part of the area between Spruce Pond and Rocky Ridge Pond, and (c) west in the northwest corner near King George IV Lake. These divergent flows may be attributed to relatively thin ice conditions, which resulted in ice flow being controlled by topography and the direction of regional slope. The north/south orientation of possible recessional moraines to the east and south of King George IV Lake indicates that retreat of ice in this area was eastward. The highlands in the central and north-central part of the map area were the last areas to be deglaciated.

DISCUSSION

The primary objective of surficial mapping is to provide information on the nature, distribution, and texture of glacial sediments. To properly interpret geochemical anomalies, resulting from either detailed or regional soil geochemistry, it is necessary to recognize and understand the factors that have influenced them. The effect upon geochemical values by variations in the till matrix, till geology, and the type of till being sampled, e.g., lodgement, meltout, should be considered. The data generated by this project will be used to assess the importance of these variables and to establish some guidelines for the interpretation of soil and till anomalies, particularly as it pertains to gold exploration in this area of southwestern Newfoundland.

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DETAILED AGGREGATE ASSESSMENT PROJECT - INSULAR NEWFOUNDLAND

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ABSTRACT

This report summerizes the results of 1985 field work to assess the aggregate potential in the St. Barbe area of the Great Northern Peninsula, and the old Norris Arm highway area of Central Newfoundland.

The study has verified that the St. Barbe area has a general lack of surficial aggregate materials, and that the old Norris Arm highway area contains adequate amounts of aggregates (in a glaciofluvial terrace). However, most of the latter deposit has been sterilized by cabin development; extensive bog cover over the remaining area will make quarrying difficult.

INTRODUCTION

It became evident with the completion of the Inventory of Aggregate Resources Project in 1981 that more detailed information on aggregate resources in specific areas of the province would be required. Municipal and other planning agencies were requesting more detailed information on aggregate resources, in an effort to reduce the size of the reserve areas. This project was initiated in 1982 in order to define accurately those areas with highest aggregate potential or those areas necessary to meet the local aggregate requirements. To date, 34 planning areas have been completed, in addition to a number of special projects.

Most of the 1985 field season was spent in the office, compiling maps and open file reports on previous work under this program. However, a two-week period was spent on a detailed aggregate resource assessment in the St. Barbe area of the Great Northern Peninsula and in the Norris Arm area of central Newfoundland (Figure 1).

FIELD PROGRAM 1985

Prior to field work, all available aggregate resource data was compiled. From this data and a review of airphotos, target areas were selected for field study.

Field work involved vehicle traversing along all roads and trails throughout each area to update data on previously-sampled surficial deposits (Kirby *et. al.*, 1983). Foot traverses were conducted in areas of potential quarry development. Backhoe testpitting was usually conducted to determine the extent, quantity and quality of the deposit, if reasonable access was available. Otherwise, shallow, hand-dug pits were used.

Mapping in the St. Barbe area was plotted on 1:50,000 scale base maps, whereas mapping in the Norris Arm area was plotted on 1:12,500 scale orthophoto maps.

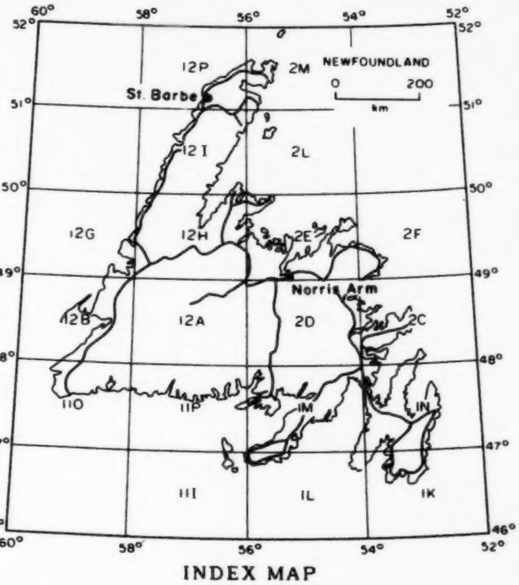

Figure 1: *Location map of aggregate assessment areas, 1985 field season.*

A total of 60 aggregate and rock samples were collected during the 1985 field program. Samples of unconsolidated aggregates containing plus 8 mm size material were field sieved and a split of the minus 8 mm fraction was retained for further laboratory sieve analysis (Kirby et al., 1983). A split of the minus 31.5/plus 16 mm pebble fraction was retained for lithological and petrographic analyses.

Study Results

St. Barbe area. This study has verified that the area lacks any significant amount of surficial aggregate material. The better quality deposits have been used in the construction of the Northern Peninsula highway with little materials remaining to meet local needs. A raised marine-beach deposit at

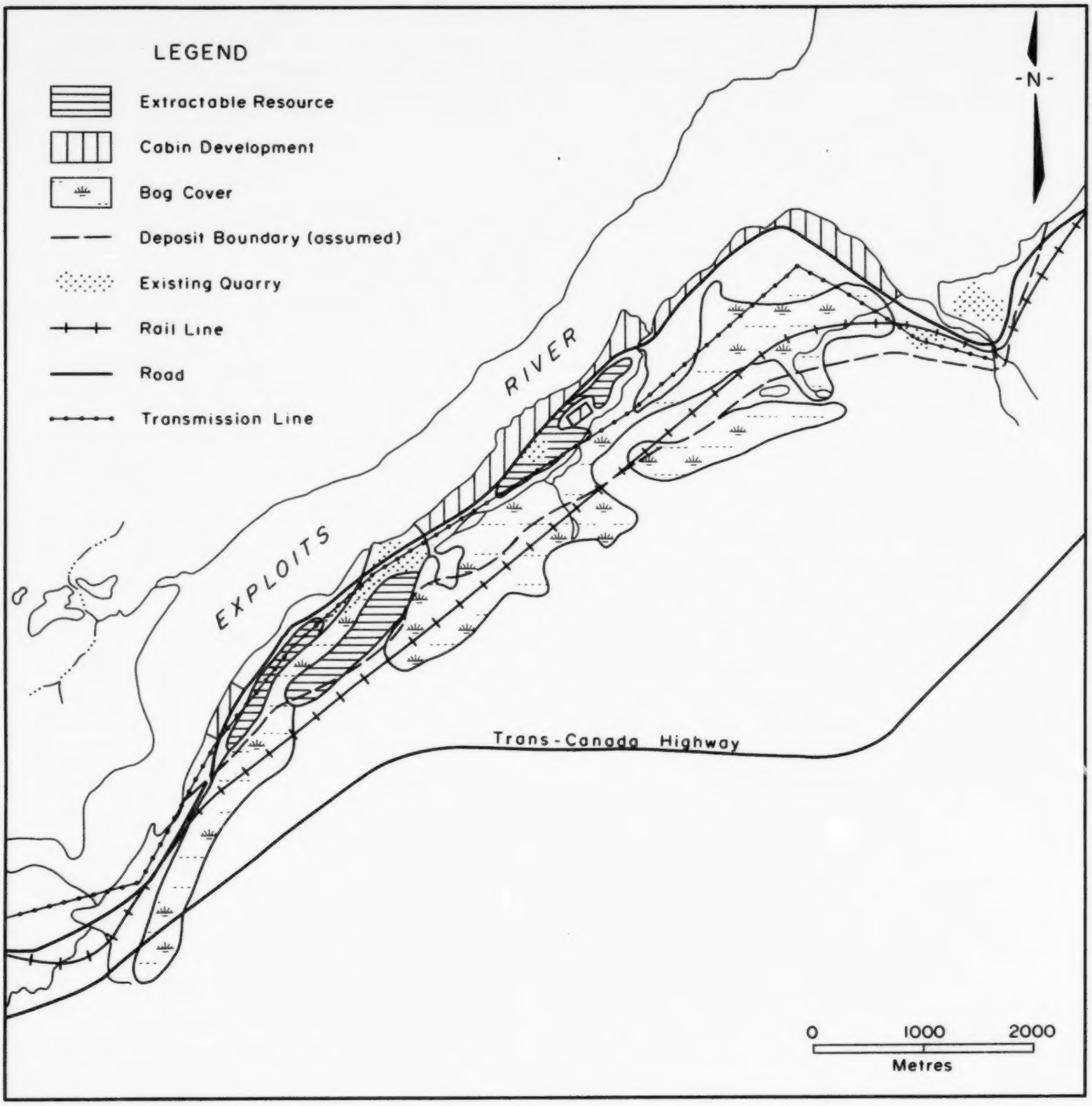
LEGEND
Extractable Resource
Cabin Development
Bog Cover
Deposit Boundary (assumed)
Existing Quarry
Rail Line
Road
Transmission Line
-N-
EXPLOITS
RIVER
Trans-Canada Highway
0
1000
2000
Metres

Figure 2: *Distribution of extractable aggregate resources within the glaciofluvial deposit along the Exploits River.*

Pigeon Cove was used until recently to supply local needs; a conflict between local residents and the contractor has resulted in the closure of this operation. Extensive areas of the coast have been stripped of their thin veneer (1 m) of aggregate material (shingle beach), leaving large barren areas that are now susceptible to coastal erosion. Bedrock in the inland area is covered by a thin veneer (1 m) of marine sediment. The marine sediment is suitable for fill but large areas would have to be stripped to obtain any significant volume of material.

There are a large number of rock quarries scattered throughout the area. The underlying carbonate rocks are suitable for use as aggregates but the cost of blasting and crushing is prohibitive for contractors serving this small population base.

Old Norris Arm highway. Due to uncontrolled development along the old Norris Arm highway, the Department of Municipal Affairs is preparing a development plan for the area. The Department of Mines and Energy was contacted and a resource-evaluation program was conducted in the area, to ensure that areas of aggregates are set aside for extraction.

The area contains a glaciofluvial terrace deposit that parallels the Exploits River (Figure 2). Field work involved the locating and delineating of glaciofluvial deposits, and determining the amount of extractible material in areas suitable for quarry development.

A total of 15 backhoe test pits were dug in pre-selected sites throughout the area to determine the extent and quality of the deposit. The results of the mapping and sampling show that the area is underlain by a dominantly sandy gravel deposit with no bedrock exposures, and most of the deposit is suitable for concrete production. However, much of the area bounded by the Exploits River and the old Norris Arm highway has been sterilized by cabin development. A large portion of the remaining area is covered by bog, which may make quarry development more difficult.

Planned Work

Maps and laboratory analyses are currently being compiled for inclusion into reports that will be forwarded to the Department of Municipal Affairs for follow-up action.

ACKNOWLEDGEMENTS

The author wishes to thank Dave Taylor for his assistance in the field and Christine Blackwood for her work in the laboratory. Jerry Ricketts, Martin Batterson and Doug Vanderveer reviewed the report.

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Mineral Development Division, Report 86-1, pages 291-296

DETAILED AGGREGATE MAPPING RELATED TO CONCRETE PLATFORM CONSTRUCTION

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ABSTRACT

This report describes an aggregate resource study in the Placentia Bay area, where large quantities of aggregate material will be in demand during the construction of offshore concrete platform structures. The study was designed to map areas of greatest aggregate potential. Results, to date, indicate that there are adequate shoreline deposits from which barges can provide a cheap means of transportation. The Swift Current deposit is possibly the largest and most suitable shoreline deposit for production of a high quality, fine aggregate for use in concrete.

INTRODUCTION

During the 1985 field season, detailed aggregate resource mapping was conducted in the Placentia Bay area (Figure 1) to support developments related to concrete platform construction. Large quantities of sand and gravel will be required on a continuous basis during the construction periods. An estimated volume of 140,000 to 150,000 m^3 of sand will be required in the platform structure. Another 1,000,000 m^3 of crushed rocks, gravel, silt and clay will be needed for the structure and related activity, e.g., cell fill for the service dock, access roads, and a causeway (Kristiansin, 1985 and Clark, 1985). For this reason, detailed aggregate studies were undertaken in potential resource areas, concentrating on the Arnold's Cove to Swift Current area at the head of Placentia Bay. These areas are within a reasonable distance to the proposed construction site at Adams Head (see also Bragg, *this volume)*. Since construction will take place in a coastal area, and will require barging once the concrete base is floated out of the dry dock, most sampling was conducted in shoreline deposits.

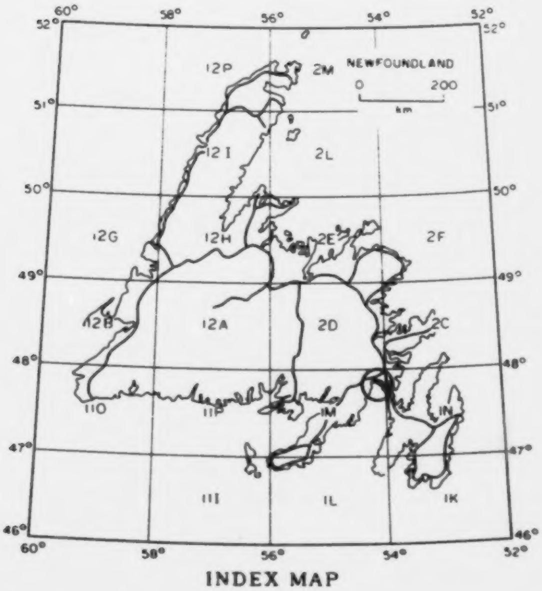

Figure 1: *Location of study area.*

The objectives of the project were to determine the quantity and quality of aggregate material in deposits within a reasonable haulage distance of Adams Head. Aggregates used in concrete platforms must have a high strength and a nonreactive chemical content. For these reasons, detailed sampling was conducted to provide material for petrographic analysis, grain size analysis and alkali reactivity testing. The testing will be done under the Canada-Newfoundland Mineral Development Agreement, 1984-1989; the alkali reactivity testing will be done by CANMET.

The height of shoreline exposures and the estimated depth of deposits in areas of hand dug test pits were recorded. These, together with the lateral extent of the deposits as determined from airphoto and/or field observations, were used to calculate available volumes of aggregate material.

Physiography

The climatic conditions of the study area consist of late springs and cool summers. Winters are cold but less severe than most areas of the province. The climate is also influenced by the cold Labrador Current which flows along the east coast of Newfoundland. Situated near the isthmus of the Avalon Peninsula, the area is subject to heavy and prolonged fogs that come off the waters of Placentia Bay and Trinity Bay. The prevalent wind direction is westerly.

The area was covered during the Late Wisconsin by glaciers that converged on Placentia Bay, generally from northwesterly and northeasterly directions. Generally there is a less than 3 m thick till veneer (composed of compacted silty materials) with numerous rock outcrops interspersed throughout. Large glacial erratics are common on hill tops. Major deposition resulted from glaciofluvial action in rounded

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This project is a contribution to the Canada-Newfoundland Mineral Development Agreement, 1984-1989

U-shaped valleys, such as in the valleys at Pipers Hole, North Harbour and Come-By-Chance. Glacial retreat resulted in small to large glaciofluvial deposits along valley floors and near the mouths of rivers entering the ocean. Wave-cut benches within glacial sediments and wave-built terraces are well developed in many places along the coast. They occur at various elevations from the present sea level to 18 m above it (Rose, 1947).

A jagged shoreline with steep to near vertical cliffs is common around most parts of Placentia Bay. With the exception of local shore ice, Placentia Bay is relatively ice free throughout the year.

FIELD PROGRAM

Field sampling was conducted on a number of deposits using a 200 m sample interval. Where possible, samples free of plant debris and topsoil were taken from natural exposures such as stream cuts, coastal sections or gullied areas. Where natural exposures were not present, samples were collected from hand-dug test pits that extended well into the C horizon (usually greater than a 2 m depth) in order to provide a fresh sample.

Data Analyses

An important objective of the field program was to obtain lithological, petrographic (Canadian Standards Association, 1973) and grain-size analyses. Field sieve analyses were conducted on samples containing material greater than 8 mm in diameter and laboratory grain-size analyses (Kirby *et al.*, 1983) were conducted on the minus 8 mm sample fractions. From the accumulated sieve data, the percentages of gravel, sand and silt/clay content of individual samples were determined.

A database management system (Scientific Information Retrieval System) designed for storage and retrieval of aggregate and surficial geology data (Atkinson, 1984) is used to record all field and laboratory data.

AGGREGATE RESOURCE AREAS

Ten deposits of aggregate resource potential were sampled in the most northern areas of Placentia Bay. The sampled deposits have individual estimated volumes that range from 16,000 m^3 to 8,360,000 m^3. The three largest deposits are located near Swift Current, Pipers Hole and North Harbour, with less extensive deposits at Black River Point and Woody Island. Deposits of low potential were sampled from: (a) two eskers 3 km west of Pipers Hole Provincial Park, (b) glaciofluvial terraces at Jack's Pond Provincial Park and Bittern Cove, and (c) small deposits at Baker Cove and Muddy Hole.

Swift Current Deposit

The Swift Current deposit is situated on the southwest shore of Swift Current and extends for 2.8 km in a northwest direction from Clay Cove (Figure 2). Its upper surface ranges in elevation from 4 to 15 m a.s.l. and is dissected by three small intermittent streams. It is overlain by dense forest growth and bog cover (30 to 40 percent). The combined A and B soil horizons reach thickness of 1 m in several localities.

The Swift Current deposit is the largest known deposit of high quality aggregate in the northern part of Placentia Bay. It is dominantly a sandy pebble gravel, with boulders and large cobbles occurring at some localities. Typical grain-size curves show less than one percent silt/clay content with a few samples showing greater than ten percent. Samples with the higher percentages were usually collected near the fringe of the deposit, or near its surface. An average petrographic value of 134 (Table 1) is based on analyses of 62 samples that gave values ranging from 100 to 300, of which only 7 were above 150.

A large deposit of stratified clay and fine sand is situated at the southeast end of the Swift Current deposit at Clay Cove (Figure 2). The clay deposit can provide a source of impervious material for use as seals in cofferdams.

The water channel flanking the Swift Current deposit is approximately 3.5 m deep at low tide. It is thus probable that mined aggregate material can easily be transported by barge to the proposed Adams Head construction site. It is expected that very little dredging (except for wharf facilities) will be needed.

Pipers Hole

The Pipers Hole deposit was originally sampled in 1978 (Kirby, *et al.*, 1983) under the Inventory of Aggregate Resource program. The deposit is located northwest of Mooring Rock Cove (Figure 2). It reaches an elevation of approximately 11 m a.s.l., tapering off gently toward the southeast where it has a thickness of less than 1 m a.s.l. The main part of this deposit is covered by barrens, including 1 to 1.5 m of peat (Tucker, 1979) and stunted tree growth. The lower region near the coast is bog covered and, because the deposit is thin above the water table, it has little potential for mining of sand and gravel.

The Pipers Hole deposit has 60 percent sand content and is overlain by 1 to 2 m of pebble gravel in many areas. An average petrographic value of 128 is based on 7 samples (collected in 1978 and 1985) that ranged in value from 100 to 180.

If the Pipers Hole deposit is used in concrete platform construction, with barging as the mode of transportation, dredging would be required along a 2 km stretch of shallow water (0.5 m at low tide) from Cape Pine to Mooring Rock Cove in the upper part of the Swift Current channel. This deposit has been quarried since 1974 and is approximately 20 percent depleted. It is presently being used by two operators. The Department of Transportation extracts sand for use in ice control, and Atlantic Concrete (formerly Lundrigan's East) mines the deposit as a source of blending sand for use in high strength concrete and cement blocks.

North Harbour

The North Harbour deposit is situated at the north end of North Harbour in the Caplin Cove area, and near the mouth of the North Harbour River (Figure 3). It is composed of a glaciofluvial terrace, dissected by several small streams. The deposit, which is separated into two areas by the North Harbour River, a designated salmon river, is covered by dense forest growth.

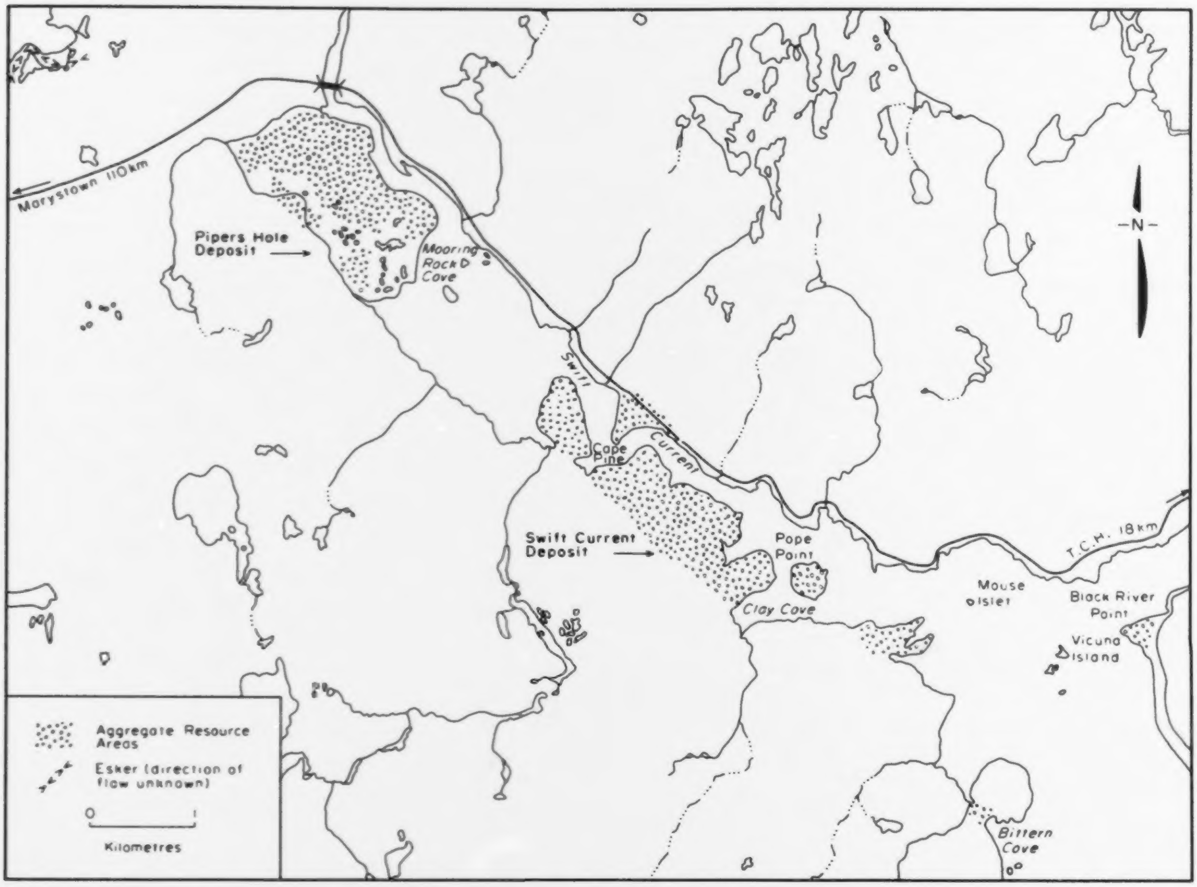
Marystown 110km
Pipers Hole Deposit
Mooring Rock Cove
Swift Current
Cape Pine
Swift Current Deposit
Pope Point
Clay Cove
Mouse Islet
Black River Point
Vicuna Island
T.C.H. 18km
-N-
Bittern Cove
Aggregate Resource Areas
Esker (direction of flow unknown)
0
1
Kilometres

Figure 2: *Aggregate resource areas at Pipers Hole, Swift Current, Black River Point and Bittern Cove.*

Analyses of 33 samples in this area (Table 1) indicate a higher sand and silt/clay content than deposits at Swift Current and Pipers Hole. Petrographic values are also much higher, with an average of 223 based on 14 samples that had values ranging from 130 to 390. Although certain sections of this deposit could be used to produce a good quality concrete, it is generally of substandard quality and not suited for a massive concrete construction project.

Woody Island

The Woody Island deposit, situated on the northeastern side of Woody Island (Figure 4), is surrounded by deep water and is closer to the Adams Head construction site than any other deposit. It is partly forested, and has some barrens and a few cleared areas.

An average petrographic value of 127 is based on analyses from six samples, ranging from 110 to 150. The average silt/clay content is 1 percent which is lower than any of the larger deposits listed. The 77 percent average for sand content (Table 1) is 7 percent lower if the values from 5 sand samples taken in the northeastern part of the deposit are excluded. This would increase the gravel content from 22 percent to 30 percent.

Black River Point

The Black River Point deposit is located on the southern shoreline at the entrance to Black River Harbour (Figure 2). It has a maximum height of 8 to 12 m a.s.l. and, except for a few cleared areas, is covered by tree growth. An average petrographic value of 103 was calculated from analyses of ten samples with values ranging from 100 to 120. The Black River Pond deposit has the best petrographic qualities of all shoreline deposits sampled.

The deeper water along this shoreline will provide easy access if aggregate material is transported by barge from the Black River Point deposit. A road from Garden Cove to the Burin Peninsula Highway runs along the eastern side of the deposit.

Esker Deposits

Two eskers were located 3 km west of Pipers Hole Provincial Park near the Burin Peninsula Highway. These are not potential source areas of aggregate material for concrete platform construction, but would provide a high quality aggregate for local use such as road upgrading. The eskers are 1 to 1.5 km from the highway and are situated in an area of

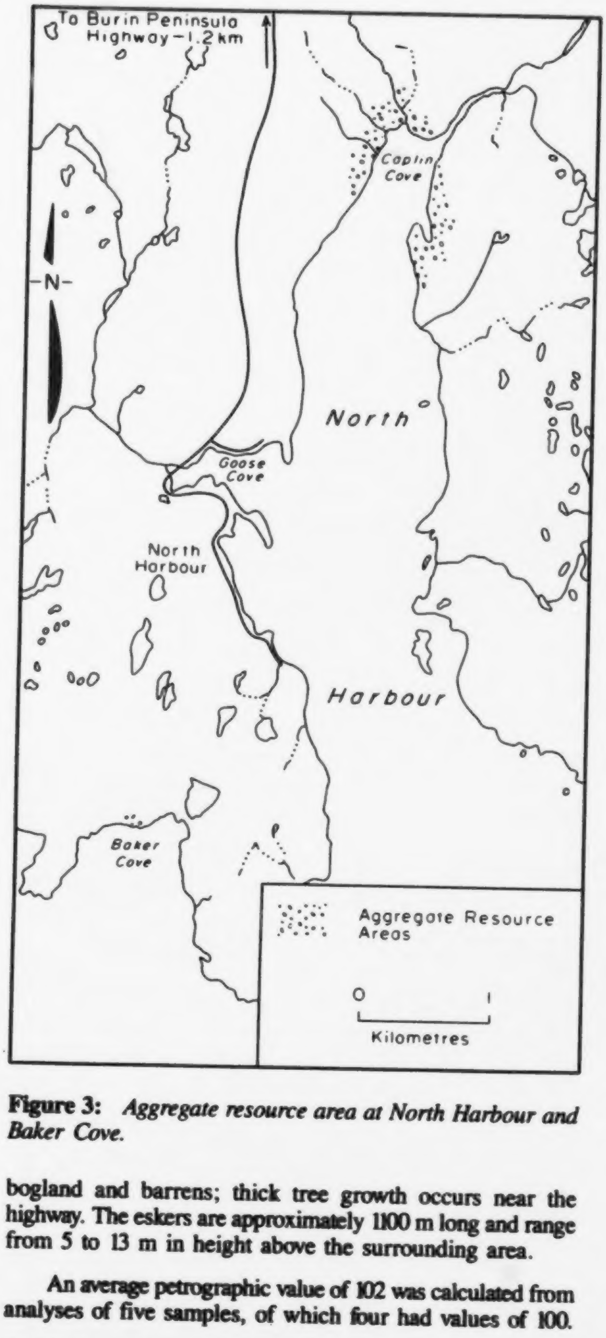
To Burin Peninsula
Highway – 1.2 km
-N-
Caplin Cove
North
Goose Cove
North Harbour
Harbour
Baker Cove
Aggregate Resource Areas
0
1
Kilometres

Figure 3: *Aggregate resource area at North Harbour and Baker Cove.*

bogland and barrens; thick tree growth occurs near the highway. The eskers are approximately 1100 m long and range from 5 to 13 m in height above the surrounding area.

An average petrographic value of 102 was calculated from analyses of five samples, of which four had values of 100.

Jack's Pond Provincial Park

The Jack's Pond Provincial Park deposit is situated near Great Southern Harbour, within the boundaries of Jack's Pond Provincial Park in the Sunnyside map area (1 N/13). The vegetation in this area consists of thick tree growth.

An average petrographic value of 187 was obtained from four samples with values ranging from 120 to 280. These high values indicate the material is of poor quality and not useable in most concrete projects. Deposits of compacted silty tills were sampled adjoining this shoreline, glaciofluvial, gravel deposit. These tills have 30.5 percent gravel, 40.3 percent sand and 29.2 percent silt/clay content.

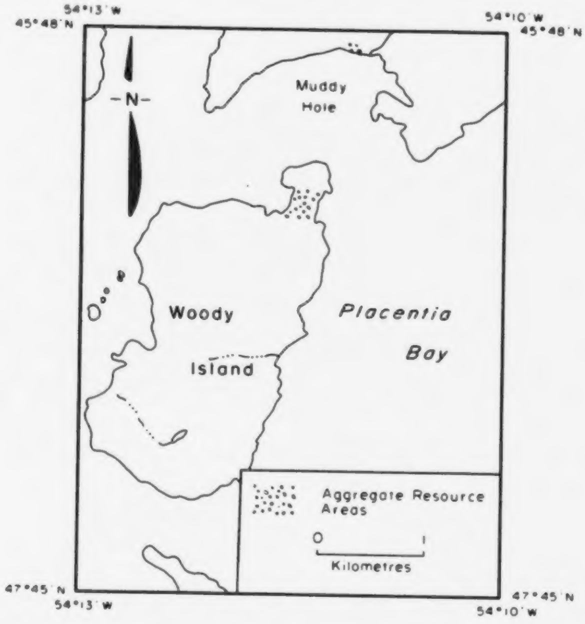
54°13'W
45°48'N
54°10'W
45°48'N
-N-
Muddy Hole
Woody
Island
Placentia
Bay
Aggregate Resource Areas
0
1
Kilometres
47°45'N
54°13'W
47°45'N
54°10'W

Figure 4: *Aggregate resource area at Woody Island and Muddy Hole.*

Bittern Cove

The Bittern Cove deposit is situated in a sheltered cove 2 km southeast of the Swift Current deposit (Figure 2). Thick tree growth covers most of the deposit.

The 73 percent sand content shown in Table 1 is the second-highest sand concentration of all deposits sampled. Petrographic analyses have been conducted on only two samples, with respective values of 100 and 110. This is a high quality material but is of insufficient quantity for the required project.

Baker Cove

Located in a cleared area south of North Harbour, the Baker Cove deposit (Figure 3) is predominantly comprised of a sandy gravel. Its isolation, small size and high petrographic values (170 to 240), based on analyses of two samples, make it a very poor deposit for use in any construction project.

Muddy Hole

The Muddy Hole deposit is situated in a forested area 1 km north of Woody Island (Figure 4). Similar to the Baker Cove deposit, its isolation, small size, high silt/clay content and poor quality reduces its potential for use in offshore construction projects.

Table 1: Summary and comparisons of aggregate deposits sampled in the northern part of Placentia Bay.

Deposit	Cubic Meters	Number of Samples Collected	Average Petro-graphic Number	% Gravel (+ 2 mm)	% Sand (+0.074 mm to - 2 mm)	% Silt (-0.074 mm)	Comments
Swift Current a) Sand/Gravel	8,160,000	87	132	40	57.35	2.65	Predominantly medium to fine grained sand with the highest percentage of particles occuring between the 0.5 to 1.0 mm range. A clay deposit is situated at the southeast end of the Swift Current deposit
b) Clay (Clay Cove)	200,000	5		0	29.14	70.86	
Pipers Hole	5,250,000	15	128	38	60	2	Cross-bedded, ripple-laminated sands and pebble gravels exposed in an active quarry. Dominant particle size occurs between the 0.25 to 0.5 mm range. The deposit is overlain by 1 to 1.5 m of peat
North Harbour	2,048,000	33	223	28	64	8	Glaciofluvial terrace dissected by several small streams. Dominant particle size occurs between the 0.25 to 0.5 mm range
Woody Island	825,000	17	127	22	77	1	Fine to medium sands with dominant particle size occuring between the 0.25 to 0.5 mm range
Black River Point	600,000	14	103	37	61	2	Predominantly sands and sandy gravel with minor cobble gravel near the surface. The dominant particle size occurs between the 0.5 to 1.0 mm range
Eskers (3 km west of Pipers Pond Provincial Park)	330,000	5	102	67	32.50	0.50	Pebble, cobble gravel with dominant particle size occuring between the 16 to 31.5 mm range
Jack's Pond Provincial Park	240,000	5	187	42	54	4	Coarse to medium sandy gravel with dominant particle size occuring between 2.0 to 4.0 mm range
Bittern Cove	202,300	5	105	26	73	1	Coarse to fine sand and pebble gravel with the dominant particle size occuring between the 2.0 to 4.0 mm range
Baker Cove	22,400	2	210	53.55	46.20	0.25	Medium to coarse sandy pebble gravel with the dominant particle size occuring between 0.5 to 2.0 mm range
Muddy Hole	16,000	3	120	25	54	21	Medium sandy gravel and silt with silt/clay being the dominant particle size

Note: Estimated quantities given in table are based on airphoto analysis and field investigation of extent and depth of shoreline deposits. Percentages are based on a compilation of individual samples and do not take into account extent and depth of deposits at any one locality.

CONCLUSIONS

Several deposits of sand and gravel sampled in the Placentia Bay area are large enough to supply the quantity of aggregate material required in the construction of offshore concrete platforms. Additional testing will be required on these deposits to determine their compressive stength and their chemical reactivity under strenuous environmental conditions. Sixteen samples have been arbitrarily selected for alkali reactivity testing, sponsored under the Canada-Newfoundland Mineral Development Agreement, 1984-1989, using the resources of CANMET.

The extent and depth of underlying layers in deposits sampled during the 1985 field season could not be determined from exposures in shallow hand dug pits. For this reason further sampling (including drilling) will have to be conducted on any selected deposit for continued geotechnical testing.

Many deposits sampled are too small and/or have poor aggregate qualities, i.e., unacceptable petrographic values and/or too high silt/clay content, rendering them unsatisfactory for use in quality concrete. These deposits should be ignored for use in concrete platforms.

The Woody Island and Black River Point deposits may lack sufficient quantities to establish a major quarry operation, despite their good petrographic values and low silt/clay content. These may, however, generate interest if the larger deposits were proven unsuitable.

The three largest deposits at North Harbour, Pipers Hole and Swift Current individually have the quantity of material required, but quality and access are variable. The North Harbour deposit may not be developed because of the poor petrographic qualities and/or high silt content in most sections of the deposit. However good petrographic numbers, and samples with low silt/clay contents were obtained in some sections.

Analyses of aggregate samples collected from the Pipers Hole deposit indicate it is a good quality concrete aggregate in most localities. However, it is situated in an area where dredging will be required to allow barges to navigate the upper part of Swift Current. Otherwise, trucks will have to be used to transport the aggregate material to the construction site or to an area where barges could be loaded. Whichever method is used, a cost increase will occur as opposed to other shoreline deposits closer to Adams Head. In addition, this deposit is presently used to meet land use requirements for ice control and high strength concrete, and consideration must be made to ensure this deposit is not depleted for these uses.

Sand and gravel in the Swift Current deposit are in a suitable location and, in most sections, have good petrographic qualities and low silt/clay content. It is also the largest known deposit in the Placentia Bay area and therefore the most likely to be developed during construction of concrete platforms.

ACKNOWLEDGEMENTS

The author wishes to thank Jim Rodgers for his cheerful and capable assistance and his lengthly conversations during the long days of summer. Baxter Beck, the park ranger at Pipers Hole Provincial Park, is thanked for his friendly discussions and helpful advice on the terrain of the Swift Current and Pipers Hole areas.

A critical review by Fred Kirby, Martin Batterson and Doug Vanderveer resulted in substantial improvements to this manuscript.

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RECONNAISSANCE STUDY OF BEDROCK AGGREGATE POTENTIAL FOR OFFSHORE AND INDUSTRIAL USE

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ABSTRACT

In 1985 a reconnaissance study of bedrock quarries for offshore aggregate potential and industrial use was initiated on the Burin and Avalon peninsulas. On the Burin Peninsula special emphasis was placed on the Marystown - Spanish Room and Swift Current areas, where a total of 119 sites were visited and 156 samples taken. On the Avalon Peninsula special emphasis was placed on the Come-By-Chance - Adams Head area, the proposed construction site of concrete platforms to be used in the Hibernia offshore oil development. A total of 138 sites were visited and 131 samples taken. Geotechnical properties of the bedrock, such as geological features, deleterious substances, abrasion, soundness, alkali-reactivity and petrographic factors, are under study.

INTRODUCTION

The announcement of the use of concrete gravity-based structures (GBS) as platforms for the development of offshore oil at Hibernia, coupled with the fact that there is already a shortage of unconsolidated aggregate material on the Avalon and Burin peninsulas, is creating the need for alternate sources of aggregate material. Bedrock is a suitable alternative due to its quantity and usually homogeneous characteristics.

During the 1985 field season, an evaluation of the aggregate potential of bedrock quarries on the Burin and Avalon peninsulas in eastern Newfoundland (Figure 1) was undertaken. This assessment is to determine the quality and quantity of bedrock aggregate available for offshore and industrial uses. Ricketts (*this volume*) has concentrated on the unconsolidated aggregate deposits in the same areas and his work complements this study.

FIELD WORK

Field work consisted of traverses along the Trans-Canada and Burin Peninsula highways, and various side roads, including visits to all rock quarries in the area. Road-cuts were also sampled where no rock quarries are present. Foot traverses were done in selected areas along the coastline.

During the first six weeks of the field season, work was centred on the Burin Peninsula, and for the last eight weeks, work was carried out on the Avalon Peninsula. The Marystown - Spanish Room and Swift Current areas on the Burin Peninsula, and the Come-By-Chance - Adams Head area on the Avalon Peninsula, because of their geographic location and deep, safe harbours, are potential sites for offshore supply bases and concrete platform construction.

Field investigations at each quarry consisted of representative sampling, determining (where possible) land ownership and present use, recording thickness of overburden, and making general geological observations. These are described below.

Representative Sample

At least one representative sample (1 kg) was collected from each quarry or site. However, 2 to 5 samples were commonly taken if the quarry were large, if there were a number of different rock types present, if the degree of weathering varied, or if veining and alteration zones were observed. At selected sites larger samples were taken for laboratory analyses.

Ownership and Use

The ownership of each quarry, whether operated by government, i.e., Department of Transportation, or privately owned, was recorded. Many rock quarries are currently controlled by the Department of Transportation although a significant number of these (30 to 55 percent) are depleted of reserves. Most of the quarries (greater than 95 percent) were opened to supply materials for use in road construction and the remainder are used in the production of ready-mix concrete.

Rock Types and Uses

The rocks types on the Burin Peninsula are mainly volcanic rocks (basalt, rhyolite, tuff, agglomerate and breccia) of the Love Cove Group (Jenness, 1957), Burin Group (Greene, 1973) and Marystown Group (Strong *et al.*, 1978). These rocks usually have a petrographic number of 1, and thus form excellent aggregate material. However, due to weathering in some areas, the petrographic number may range up to 6. Sporadic outcrops of sedimentary rocks (shale, sandstone, limestone) and intrusive rocks (granite, gabbro and diorite) were observed.

The western part of the Avalon Peninsula consists of Precambrian sedimentary rocks (siltstone, sandstone,

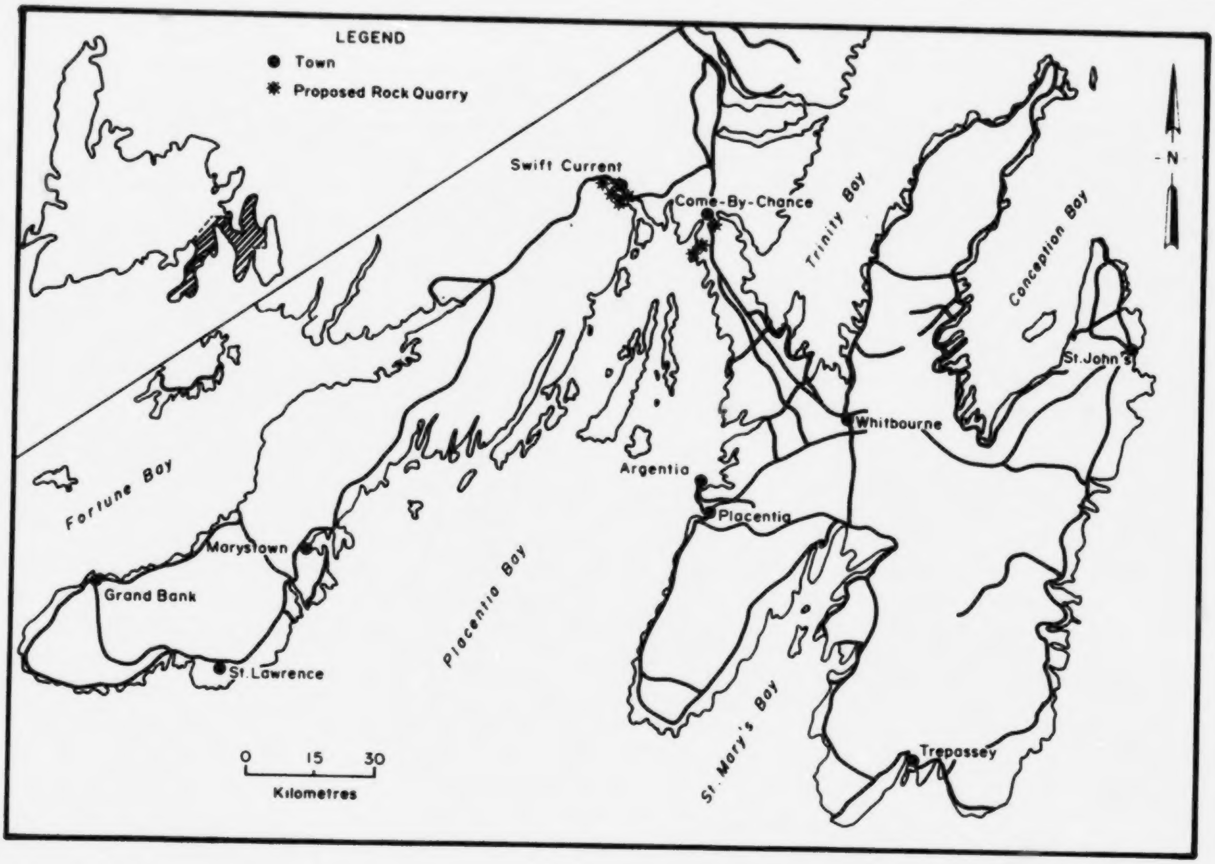

Figure 1: *Field area coverage for bedrock aggregate survey during the 1985 field season, showing proposed rock quarry sites.*

graywacke, chert, shale, conglomerate) of the Musgravetown (Hayes, 1948) and Connecting Point (Hayes, 1948) groups, and acidic to mafic volcanic rocks of the Bull Arm Formation (McCartney, 1958) and the Harbour Main Group (Rose, 1952). There are sporadic occurrences of intrusive rocks (granite and gabbro) throughout the sedimentary and volcanic rocks.

The volcanic rocks that occur on the Burin and Avalon peninsulas all have petrographic factors of 1 to 6; the factor is 1 where rocks are fresh. They may all be used for industrial purposes if they are fresh and free of deleterious substances. The sedimentary rocks (sandstone, siltstone, limestone, graywacke, and chert) have petrographic factors of 1 to 6; the factor is 1 where rocks are fresh.

Shale has a high petrographic factor of 10 due to its softness, friability and mineral content. It is normally used as a rare material in portland cement, and in some lightweight aggregates. Shale may also be used as a fill or ballast for road construction.

The conglomerates in the study area have petrographic factors of 1 to 10 and a usual factor of 6 where fresh. It is not normally used as concrete aggregate because of its weak internal bonding, which may cause breakdown during each handling of the rock. However, some well cemented homogeneous conglomerates, i.e., those composed mainly of volcanic or granitic clasts, may be used as aggregate material, such as armour stone.

Geological Features

The geological structures that were considered during the investigation are faults, fractures and joints. These affect the breakage pattern of the bedrock, and affects the cost of quarrying, i.e., amount of explosives required, and the amount of waste product, such as excessively oversized or undersized blast material. Microfractures are also important because they may affect the compressive strength of the rock. These will be examined by thin section analysis.

The following factors are equally important when quarrying bedrock:

1) Grain size - generally, the finer the grain size the harder the rock.
2) Bedding structures - important because rocks tend to break more easily along bedding planes and laminae.
3) Flow structures - in igneous rocks these tend to be planes of weakness.
4) Mineral alignments - common in metamorphic rocks, these tend to be planes of weakness and thus important

Table 1. Rock type and Petrographic factors

Rock Type	Classification	Factor
Carbonates (hard)	good	1
Carbonates (sandy, hard)	good	1
Sandstone (hard)	good	1
Gneiss (hard)	good	1
Quartzite (coarse grained)	good	1
Graywacke—arkose	good	1
Volcanic (slightly weathered)	good	1
Granite—diorite	good	1
Trap	good	1
Magnetite	good	1
Pyrite (disseminated in trap)	good	1
Iron-bearing quartzite	good	1
Sedimentary conglomerate (hard)	good	1
Carbonates (slightly weathered)	fair	3
Carbonates (sandy, medium hard)	fair	3
Sandstone (medium hard)	fair	3
Crystalline carbonates (hard)	fair	3
Crystalline carbonates (slightly weathered)	fair	3
Gneiss (soft)	fair	3
Chert and cherty carbonates	fair	3
Granite (friable)	fair	3
Volcanic (soft)	fair	3
Pyrite (pure)	fair	3
Flints and jaspers	fair	3
Carbonates (soft, slightly shaly)	poor	6
Carbonates (soft, sandy)	poor	6
Carbonates (deeply weathered)	poor	6
Carbonates (shaly clay)	poor	6
Carbonates (ochreous)	poor	6
Chert and cherty carbonates (weathered)	poor	6
Sandstone (soft, friable)	poor	6
Quartzite (fine grained)	poor	6
Crystalline carbonates (very soft, porous)	poor	6
Gneiss (friable)	poor	6
Granite (friable)	poor	6
Encrustations	poor	6
Cementations	poor	6
Schist (soft)	poor	6
Ochre	deleterious	10
Shale	deleterious	10
Clay	deleterious	10
Decomposed volcanics	deleterious	10
Slates	deleterious	10
Talc-gypsum	deleterious	10
Iron formations (very soft)	deleterious	10
Sibley formation	deleterious	10

with regard to excessive rock breakage when blasting, crushing, and during the blending of the crushed stone with cement or asphalt binders.

5) Mineralization, veining and alterations - noted because of their deleterious effect.

LABORATORY INVESTIGATION

During the on-site field investigation, rock samples ranging from 14 to 45 kg were taken for laboratory testing. Testing proposed will include the $MgSO_2$ Soundness test (ASTM-C88-73, which is used to indicate the durability of an aggregate derived from a rock sample, in relation to weathering agents. The test is done by placing a quantity of the sample in a wire mesh basket and submerging it in a solution of magnesium sulfate for 16 to 18 hours. Then the sample is dried for 8 hours at 230°F. This process is repeated a number of times and the sample sieved again. Any loss of the aggregate or crushed stone through the sieve is calculated as a percentage. The Los Angeles Abrasion tests,ASTM-C131-69 (for small size coarse aggregate) and ASTM-C535-69 (for large size coarse aggregate) are also conducted. This test consists of placing a sample of about 5,000 grams in a horizontal steel drum containing a number of steel balls. The drum is then rotated for approximately 15 minutes at 33 revolutions per minute. After the test, the sample is sieved and the percentage loss is calculated.

If the results of these tests are favorable, the sample will be further tested for alkali-reactivity (ASTM-C289-71). This test determines the potential reactivity of an aggregate with alkalies in portland cement concrete, determined by the amount of reaction during 24 hours at 80° C in 1N sodium hydroxide.

Table 2. Revised Petrographic factors for some rock types

Rock Type	Petrographic Factor Range	Usual Factor
1. Sandstone	1-6	1
2. Shale	10	10
3. Mudstone	3-6	6
4. Siltstone	1-6	1
5. Conglomerate	1-10	6
6. Arkose	1-6	1
7. Argillite	3-6	6
8. Graywacke	1-6	1
9. Chert	1-3	1
10. Limestone	1-6	1
11. Dolomite	1-6	1
12. Quartzite	1-6	1
13. Granite	1-6	1
14. Gabbro	1-6	1
15. Diorite	1-6	1
16. Granite-diorite series	1-6	1
17. Felsic volcanics	1-6	1
18. Mafic volcanics	1-6	1
19. Intermediate volcanics	1-6	1
20. Felsic-mafic volcanics	1-6	1
21. Pyroclastics	3-6	3
22. Metavolcanics	3-6	3
23. Gneiss	1-6	3
24. Schist	3-10	6
25. Phyllite	6-10	6
26. Marble	1-6	1
27. Slate	10	10
28. Amphibolite	6-10	6
29. Ultramafic	6-10	6
30. Metasediments	1-6	3
31. Iron formation	6-10	6
32. Drift deposits	Any or all of the above	Any or all of the above

In house petrographic examination (ASTM Method C-295-65(1973) and CSA standard A23.2, 1973) will be done be using hand specimens and thin sections. This test involves determining the petrographic number by using the sum of the products of the petrographic factors. The petrographic factors 1, 3, 6, and 10 (CSA Standard A23.2, 1973) are an indication of the quality of the rock (Tables 1 and 2). The quality is usually affected by the presence or absence of deleterious substances and/or weathering (Table 3). The lower the petrographic number the more superior the rock quality, which is expressed in the range of 100 to 1000, e.g., a clean, hard, unweathered granite would normally have a petrographic number of 100, whereas a friable, soft shale would be 1000.

Table 3. Affect of weathering on petrographic factors

Petrographic Factor	Weathering Grade	Final Petrographic Factors
1	1, 2	1,2
	3	3,4,5
	4, 5	6,7,8,9
	6	10
3	1, 2	3,4,5
	3, 4	6,7,8,9
	5, 6	10
6	1, 2	6,7,8,9
	3, 4, 5, 6	10
10	1, 2, 3, 4, 5, 6	10

SUMMARY

A total of 256 sites were visited during the field season and 286 samples collected. Thin sections will be made of all samples and petrographic analyses completed. However, only samples with fresh hard surfaces from areas which have the potential of becoming construction or supply sites for offshore development will be subjected to detailed analyses. Data on these and other sites should be available by the end of 1985 or early 1986.

A selected number of samples will be forwarded to a contract consultant to carry out the following testing: Soundness Test - ASTM C88; Resistance to Abrasion - ASTM C535 and C131; Petrographic Examination - ASTM C295; Potential Reactivity (Chemical Method) - ASTM C289; Potential Reactivity (Mortar-Bar Method) - ASTM C227; Potential Reactivity (Rock Cylinder Method) - ASTM C586; Potential Reactivity (Concrete Prism Expansion) - CSA 23.2-14A.

ACKNOWLEDGEMENTS

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CORE STORAGE PROGRAM, 1985

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Publications and Information Section

INTRODUCTION

During 1979, the Newfoundland Department of Mines and Energy started a drill core collection and storage program. The objective is to provide well maintained and representative collections of drill core from as many drilling programs as possible for the future use of the mineral exploration industry, government and university geoscientists, and other geotechnical people.

DRILL CORE COLLECTION

During the 1985 field season, drill core collection continued in insular Newfoundland and western Labrador. In insular Newfoundland, 23,106.0 m of core were collected from ten drilling projects and in western Labrador 1,513.0 m of core were acquired from drilling in the Labrador Trough. To date, the core storage program has collected 173,642.3 m of drill core, of which approximately 141,455.3 m are classified as 'open' and are available for inspection by interested persons. Figures 1 and 2 show the locations of all sites from which core has been collected, and Tables 1 and 2 give a list of the collected core.

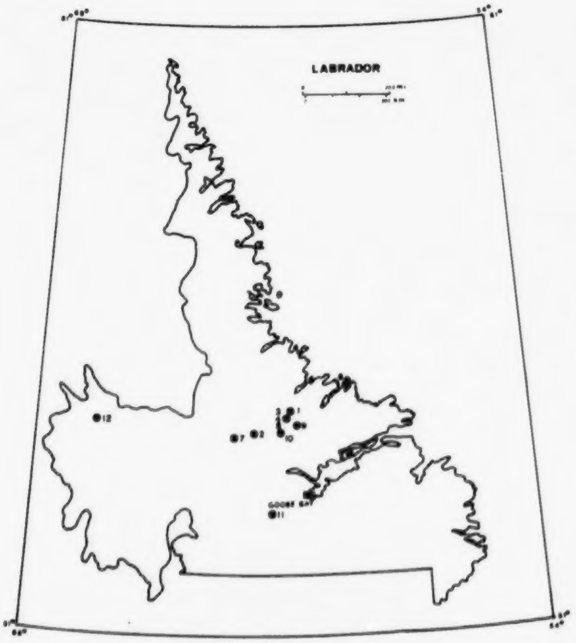

Figure 1: *Core collection sites, Labrador.*

The core storage program is presently storing 32,187 m of core from 15 drilling projects on a confidential basis. Requests for confidential storage are treated on an individual basis. Conditions and terms of confidential storage are tied to land status and are similar to the terms and conditions of confidentiality which apply to assessment reports.

The Mineral Regulations regarding drill core are given in Appendix I. No changes are planned to these regulations.

DRILL CORE LIBRARIES

The Department of Mines and Energy operates three drill core libraries, located in St. John's, Pasadena and Goose Bay (Figure 3). The St. John's library is staffed on a full-time basis, except during the field season. It has a capacity of 60,000 m of drill core. Approximately 30,000 m of drill core are being stored in the St. John's library. Most of this core is from eastern Newfoundland, from the St. Lawrence area, and the 'silica survey' drilling conducted by the provincial government during the 1960's. Drill core logs and location maps have been prepared for catalogued core. The St. John's library also contains rock cutting equipment, core splitters, a stereomicroscope, a magnetic susceptibility meter, a resistivity meter, an ultraviolet light and a McPhar TV-1 scintillometer. These facilities and equipment are available for use on approved projects by exploration geologists, university researchers, staff of the Department of Mines and Energy and other interested persons.

The Pasadena core library is also staffed on a full-time basis. This library has equipment and facilities similar to the St. John's library and has a capacity of 200,000 m of core. It has a ventilated room for storing radioactive core and a humidity-controlled room for storing salt core. There are approximately 130,432 m of core presently stored in the Pasadena library, collected from drilling sites west of Gander. The Goose Bay core library, which contains core from Labrador, is not staffed on a full-time basis. It has a capacity of 60,000 m of core, with room for expansion. Approximately 11,766 m of core have been catalogued and placed on the rack system to date.

PLANS

All 'open' drill core in our three core libraries has been catalogued and a drillhole map index and computer listing of this core are available as Open File Nfld. 1479. Drill core collection will continue in insular Newfoundland and in Labrador during the 1986 field season. An extension to the

Pasadena core library is in the planning stage. Limited space is available in all three core libraries for confidential storage of core. We encourage explorationists to use our facilities for core storage and related research.

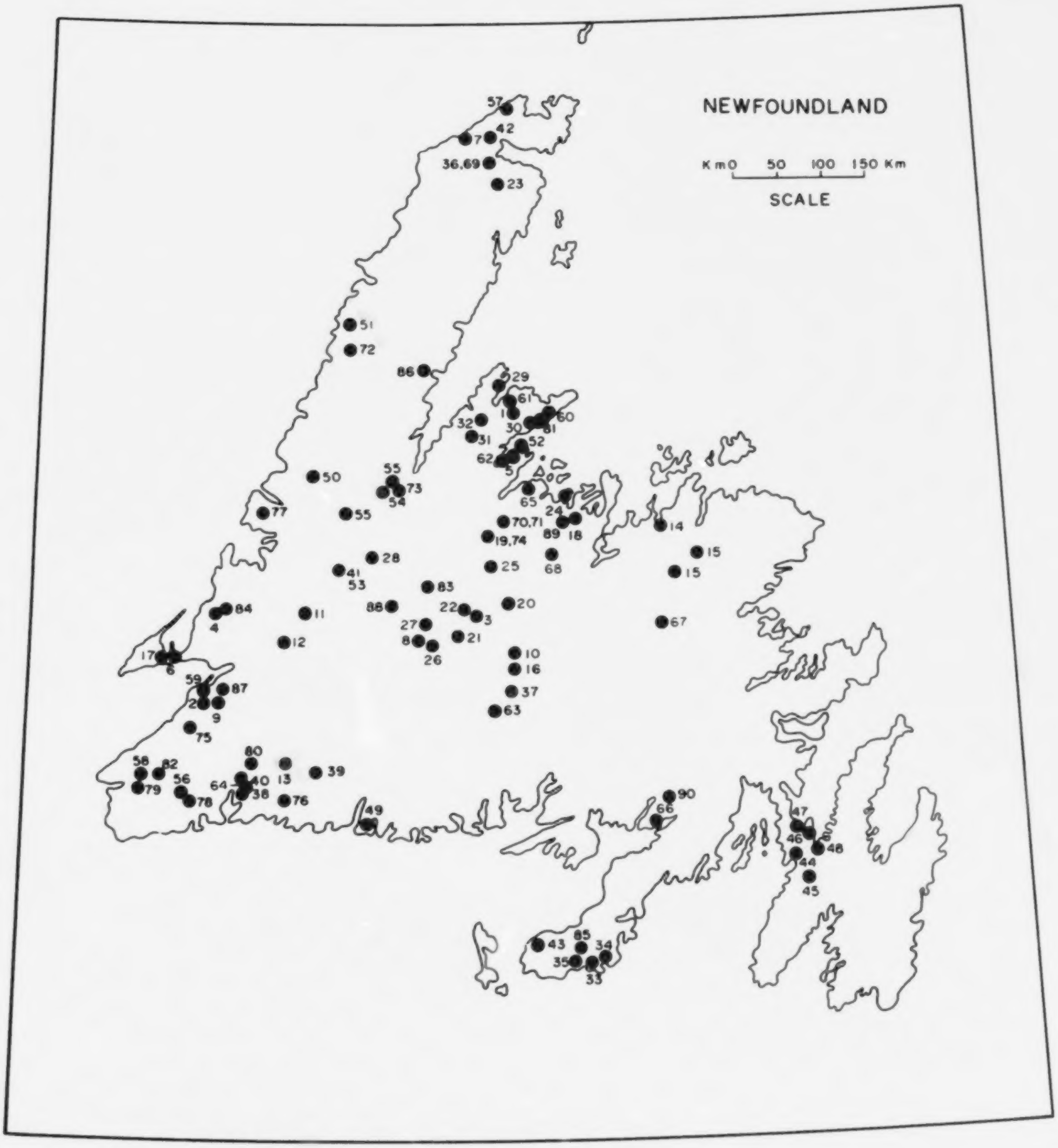
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Figure 2: *Core collection sites, insular Newfoundland.*

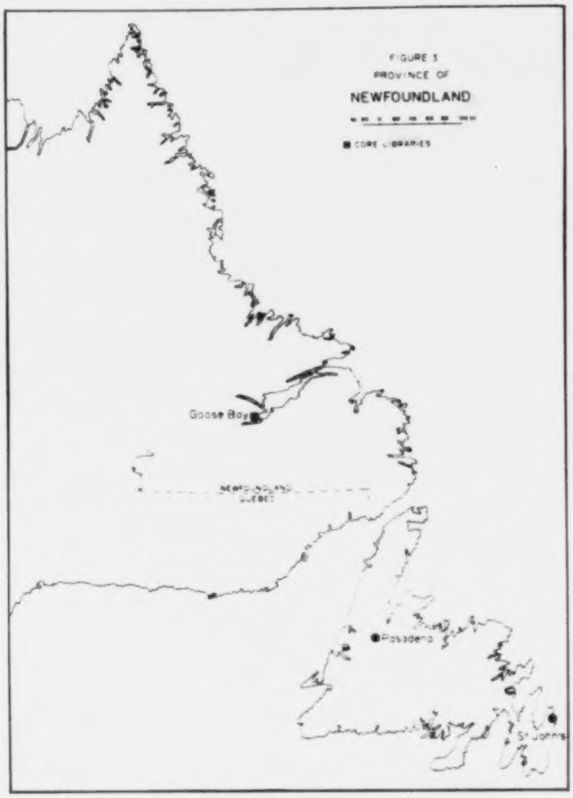

Figure 3: *Core libraries in the province of Newfoundland and Labrador.*

TABLE 1. SUMMARY OF CORE COLLECTED TO DATE - INSULAR NEWFOUNDLAND

No.	Company	Year	Property	# of Holes	Total Metres	Storage Location
1	Advocate	1967	Rambler	2	1,193.0	P
2	Amax	1976	Fischells Area	2	1,420.3	P
3	Amoco	1978	Burnt Pond	4	609.6	P
4	Beth Canada	1978	Springer's Hill	10	911.7	P
5	Boylen-Cerro		Colchester	18	1,379.2	P
6	Canadian Ref.	1970	Aguathuna	13	850.1	P
7	Chevron	1979	Eddies Cove	11	481.6	P
8	Cominco-Hansa	1973(?)	Bobby's Pond	5	431.6	P
9	Hooker Chemical	1968	Fischells	1	173.4	SJ
10	HBOG	1978	Gt. Rattling Bk.	11	818.6	P
11	HBOG	1978	Reid Lot 223	5	306.3	P
12	HBOG	1978	Reid Lot 225	2	117.0	P
13	HBOG	1978	Top Pond	1	47.1	P
14	Internat. Mogul	1974	Campbellton Area	15	1,394.5	P
15	Internat. Mogul	1975	Gander Area	12	708.7	P
16	Minorex	1978	Atlantic Lake	6	439.5	P
17	Nfld. Mines Branch		Port au Port	?	811.5	P
18	Noranda	1972	Point Leamington	3	265.8	P
19	Noranda	1973	Gullbridge	1	54.9	P
20	Noranda	1975	Leonard's Lake	3	388.6	P
21	Noranda	1975-78	Tally Pond	2	489.2	P
22	Noranda	1978	Burnt Pond	2	165.0	P

TABLE 1 *(Continued)*

No.	Company	Year	Property	# of Holes	Total Metres	Storage Location
08	Noranda	1978	Bobby's Pond	4	320.6	P
23	Shell Can. Res.	1975-76	Main Brook Area	32	1,859.3	P
24	Texas Gulf	1975	Seal Bay	8	1,104.9	P
19	Gullbridge Mines	?	Gullbridge	213	12,473.9	P
25	Consol. Morr.	1976	Lake Bond	2	419.1	P
26	L.M. & E.	?	Lake Ambrose	6	647.7	SJ
27	Kerr Addison	1974-75	Victoria Area	5	655.3	P
28	Shawmont	1977-78	Hinds Brook	28	822.9	SJ
29	Advocate	?	Priests Showing	8	774.8	P
30	Advocate	?	Nippers Harbour	7	946.1	P
31	Advocate	1976	West Pond	3	144.7	P
32	Advocate	1975	Flatwater Pond	11	907.6	P
33	ALCAN	?	St. Lawrence	?	8,153.4	SJ
34	D.S. Robertson	?	Mt. Margaret Area	?	4,463.8	SJ
35	D.S. Robertson	?	Lawn Area	?		SJ
36	Noranda	?	Round Pond Area	?	?	P
37	RIOCANEX	1976	Cold Spring Pond	1	30.0	SJ
38	Falconbridge	1979	Strickland Property	?	4,427.2	P
39	Falconbridge	1981	Burgeo Road	16	1,059.2	P
40	Long Lac Min.	1968	Strickland Property	18	975.3	P
41	Minorex	1978-80	Deer Lake	25	1,993.3	P
42	U.S. Borax	1979	Hidden Pond	11	237.6	P
43	Nfld. Mines Branch	1960's	Fortune (Silica)	3	199.9	SJ
44	Nfld. Mines Branch	1960's	Long Harbour (Silica)	6	232.5	SJ
45	Nfld. Mines Branch	1960's	Argentia (Silica)	11	731.6	SJ
46	Nfld. Mines Branch	1960's	Thornlea (Silica)	6	230.9	SJ
47	Nfld. Mines Branch	1960's	Bellevue (Silica)	7	187.1	SJ
48	Nfld. Mines Branch	1960's	Long Cove (Silica)	4	164.1	SJ
49	Nfld. Mines Branch	1960's	Grey River (Silica)	6	256.2	SJ
50	Nfld. Mines Branch	1960's	Bonne Bay (Silica)	4	197.2	SJ
51	U.S. Borax	1981	Daniels Harbour	2	804.6	P
52	Minorex	1981	Silverdale	7	203.6	P
53	Minorex	1979-80	Deer Lake	?	109.7	P
54[†]	Westfield Minerals	1978-81	Deer Lake	130	8,314.9	P
55	Northgate Expl.	1979	Deer Lake	16	2,511.5	P
56	RIOCANEX	1978-81	Cape Ray	171	20,461.0	P
57	Essex	1981	Watts Bight	4	609.6	P
58	Shell Can. Res.	1980	Codroy Valley	6	890.0	P
59	Flintkote	1979-80	Flat Bay	?	3,214.0	P
60[†]	Newmont	1981	Tilt Çove	6	864.1	P
61	Rambler Mines	?	Ming Mine	64	9,150.0	P
62	BRINEX	?	Whalesback	235	12,226.0	P
63	RIOCANEX	1976	Great Burnt Lake	9	1,463.0	P
64	St. Joe Can.	1982	Big Pond	9	707.0	P
65	Billiton	1981	Ghost Pond	3	668.0	P
66[†]	Esso Minerals	1982	Ackley Granite	5	280.0	SJ
67	HBOG	1980	Gander Lake South	7	296.1	P
68	HBOG	1980	New Bay Pond	6	356.8	P
69	NAREX ORE SEARCH	1983	Round Pond	21	402.3	P
70	U.S. Borax	1983	Handcamp	7	683.8	P
71	Falconbridge	1979	Handcamp	9	730.6	P
72	Eldorado Nuclear	1979	Portland Creek	1	113.1	P
73	Westfield Minerals	1978	Wigwam Brook	12	576.0	P
74	Dupont Canada Expl.	1983	Gullbridge	2	312.0	P
75	Nfld. Mines Branch	1983	Robinson's River	1	343.2	P
76-80	Confidential Storage	1983-5	Southwest Nfld.	49	7,769.0	P

TABLE 1 *(Concluded)*

No.	Company	Year	Property	# of Holes	Total Metres	Storage Location
81†	Rio Algom	1984	Burtons Pond	6	517.6	P
82†	Getty Mines	1984	Anguille Mountains	2	297.0	P
83†	Can. Nickel Co. Ltd.	1982-3	Badger Area	22	1,767.9	P
84	Asamera Inc.	1984	Bluff Head	7	1,101.5	P
85	BP Minerals Ltd.	1974	Burin Peninsula	11	1,188.7	SJ
86	Nfld. & Lab. Hydro	1977-82	Cat Arm	10	1,417.3	P
87†	Pronto Exploration	1980	Barachois Brook	2	977.8	P
88	NORANDA	1983	A.N.D. Charter-JB	10	1,072.8	P
89†	NORANDA	1971-84	Central Nfld.	50	11,068.3	SJ
90†	Rio Algom	1985	Ackley Granite	3	333.7	P
				Total	161,875.9	

P - Pasadena Core Library
SJ - St. John's Core Library
† Temporary Confidential Storage

TABLE 2. SUMMARY OF CORE COLLECTED TO DATE - LABRADOR

No.	Company	Year	Property	# of Holes	Total Metres	Storage Location
1	American Metal Co.	1954	Green Pond	3	16.7	GB
2	BRINEX	1972	Seal Lake	19	1,333.5	GB
3	Canadian Nickel Co.	1978-80	Moran Lake	30	2,103.1	GB
4	Mokta Can. Ltd.	1965	Moran Lake	8	220.9	GB
5	Northgate Explor. Ltd.	1980	Lake Melville	8	652.2	GB
6	Placer Devel. Ltd.	1980-81	Banana Lake	11	655.3	GB
7	RIOCANEX	1961	Ten Mile Lake	4	197.5	P
8	Shell Can. Res.	1977-79	Moran Lake	61	3,822.2	GB
9	Shell Can. Res.	1977	Sylvia Lake	3	99.4	GB
10	Shell Can. Res.	1977	Madsen Lake	2	114.8	GB
11	Nfld. and Lab. Hydro	?	Gull Island		1,037.8	GB
12	Lab. Mining & Expl. Ltd.	1979-84	Labrador Trough	38	1,513.0	GB
				Total	11,766.4	

GB - Goose Bay Library
P - Pasadena Library

APPENDIX I

MINERAL REGULATIONS RE: DRILL CORE

Preservation of diamond drill core

64. No person, whether a holder of mineral rights issued under this Act or these Regulations or not, shall intentionally abandon, discard, dump, destroy or otherwise reduce the original technical value of any diamond drill core or rotary drill cuttings obtained for information purposes within the Province or remove same from the Province, except for those sections submitted for assaying, testing, microscopic, metallurgical and beneficiation studies, without the permission of the Minister.

Minister may allow disposal or obtain core for Crown

65. (1) All persons proposing to dispose of any diamond drill core in their possession or lodged with them for safekeeping, shall notify the Minister of their desire to do so and upon receipt of such notification the Minister

(a) shall provide such persons with permission in accordance with regulation 64 or

(b) may direct his authorized representative to take possession of such drill core for the Crown and take such other action as he may deem necessary.

(2) The actions directed by the Minister under paragraph (1) shall be undertaken at the expense of the Crown.

Current Research (1986) Newfoundland Department of Mines and Energy,
Mineral Development Division, Report 86-1, pages 309-312

NEWFOUNDLAND MINERAL OCCURRENCE DATA SYSTEM

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INTRODUCTION

The Newfoundland Department of Mines and Energy initiated a Mineral Inventory project in 1971 in order to provide a readily accessible file of index cards which would summarize all the available information on known mineral occurrences in the province (Hsu, 1974). These initial compilations were carried out until 1974 and were then discontinued. About 2500 occurrences had been identified of which 1200 had been documented.

In 1976, a folio of mineral occurrences maps, plotted on black and white geological bases at a scale of 1:250,000 were published. These were accompanied by a booklet of mineral occurrence tables (Douglas, 1976a,b) which contained very brief descriptions of the mineral occurrences compiled from the Mineral Inventory File. The data was tabulated according to the following categories: name, commodity, N.T.S. area, minerals present, description, host rocks, work done, production, reserves and remarks. In addition, summary maps for insular Newfoundland and for Labrador were prepared, which showed the mineral occurrences and the N.T.S. grid, at a scale of 1:1,000,000. The occurrences were numbered such that the tables could be used as references for the summary maps as well as the larger scale maps.

The present Mineral Occurrence Data System was devised in 1978 after research into mineral inventory files across Canada and the United States. The proposed system was originally described by McArthur (1978) and Missan *et al.* (1979), and part of this paper is taken from their report. The system is designed to offer an efficient information service on all mineral occurrences in the province. It is a two-part project comprising a manual Mineral Inventory File and a computerized Mineral Index.

MANUAL MINERAL INVENTORY FILE

The manual Mineral Inventory File is part of the National Mineral Inventory and was originally proposed to continue and update the card system of Hsu (1974) and the mineral occurrence maps and tables of Douglas (1976a,b).

In 1978, a pilot project was carried out in the Stephenville (12B) map area. By April, 1979, the system was fully operational with two Mineral Inventory geologists (one responsible for insular Newfoundland and one for Labrador) and one project geologist. The number of Mineral Inventory geologists increased to a maximum of four during 1981.

The Mineral Inventory File consists of mineral occurrence descriptions that summarize all the available data on known mineral occurrences in the province. A description may be prepared for any type of occurrence from an indication to a producing mine. In preparing a description, the compiler researches all reports and publications which contain information on a particular occurrence. The location is then plotted on a 1:50,000 topographic map and the information is condensed under the following headings: name, product, owner/operator, land tenure, location and access, description, history of exploration and development, production and/or reserves, status, type of deposit, mineralogical composition, nature of mineralization and genesis, host rocks, structure of deposit, structural features and tectonic setting, metal/mineral content, geophysical expression, geochemical expression, physiographic setting, remarks and references.

All mineral occurrences for the island of Newfoundland have been compiled (see Figure 1). Areas which have been completed in Labrador are: 13I, 13J, 13K, 13N, 13O, 14C, 23I, 23J and 23O (see Figure 2). These map areas are located in the Central Mineral Belt and the Labrador Trough, which contain the majority of known mineral occurrences in Labrador. Updates are made periodically as land tenure changes and new mineral occurrences are discovered.

At present, the file consists of approximately 3000 mineral occurrence descriptions, each description containing from 3 to 10 pages. The whole file contains approximately 15,000 pages.

The file is presently being microfiched with the topographic location maps, and as they are completed, microfiche duplicates will be available upon request. Each duplicate costs $0.50 and contains several descriptions depending on their length. All areas on the island of Newfoundland have been microfiched, including 13K, 13N and 14C in Labrador.

1:250,000 scale mineral occurrence maps with updated geological bases are being prepared for printing. To date, fifteen maps have been printed and are available upon request at a cost of $3.00 each. These are 1K, 1N, 2C, 2D, 2E, 2F, 2M, 11O, 12B, 12G, 12H, 12I/2L, 12P, 13K, 13N and 14C. In addition, a 1:100,000 scale map of parts of 13J and 13O and a 1:50,000 map of 13K/5 are printed and available. These maps contain locations of all mineral occurrences in the area together with a listing of these occurrences, including the name, status and minerals present. Published maps for most of Newfoundland and some parts of Labrador will be available within a year.

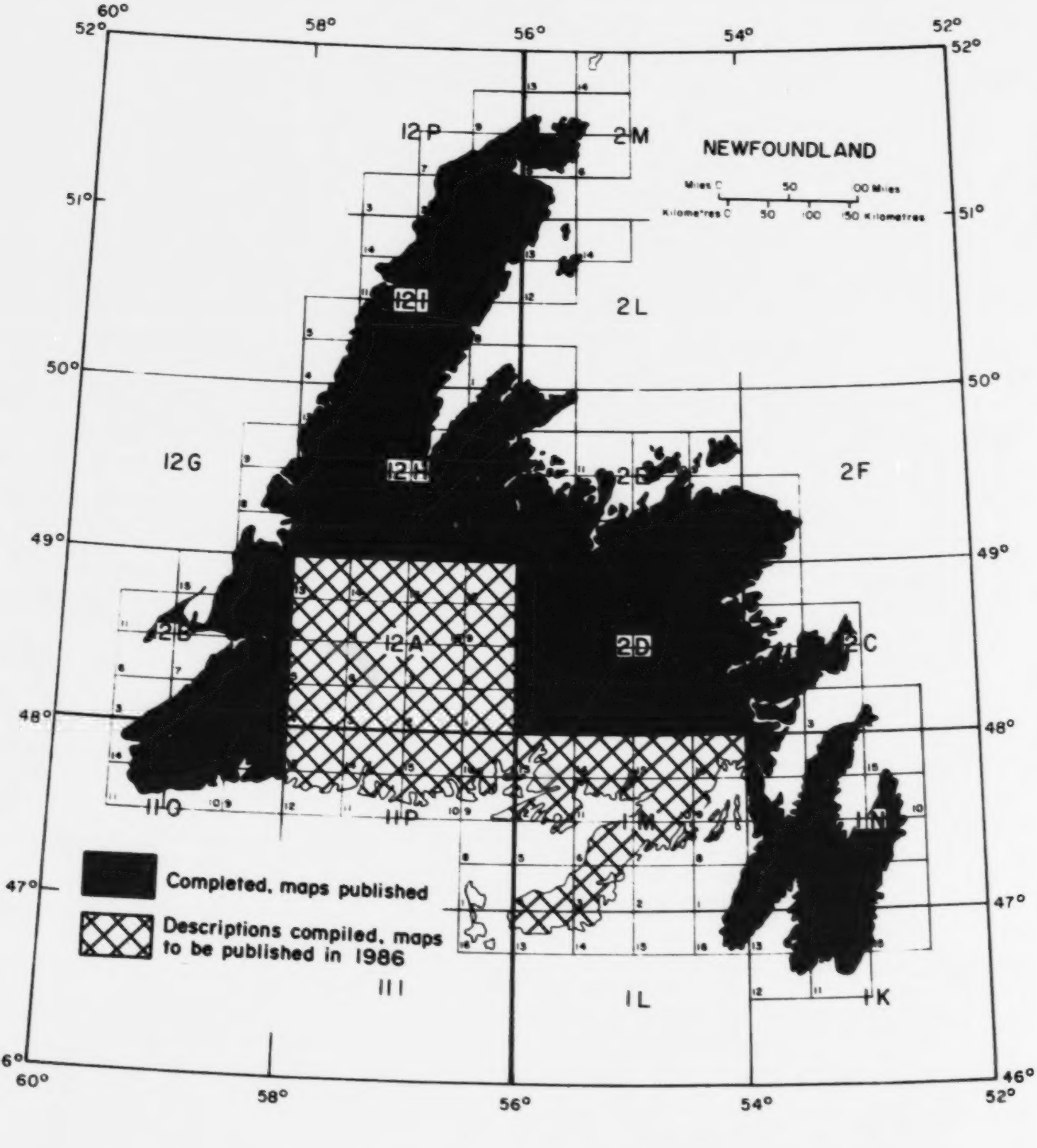
NEWFOUNDLAND
Miles 0 50 100 Miles
Kilometres 0 50 100 150 Kilometres
60°
52°
58°
56°
54°
52°
51°
50°
49°
48°
47°
46°
12P
2M
12I
2L
12G
12H
2E
2F
12B
12A
2D
2C
11O
11P
1M
1N
11I
1L
1K
Completed, maps published
Descriptions compiled, maps to be published in 1986

Figure 1: *Index map for Mineral Occurrence Data System project, insular Newfoundland.*

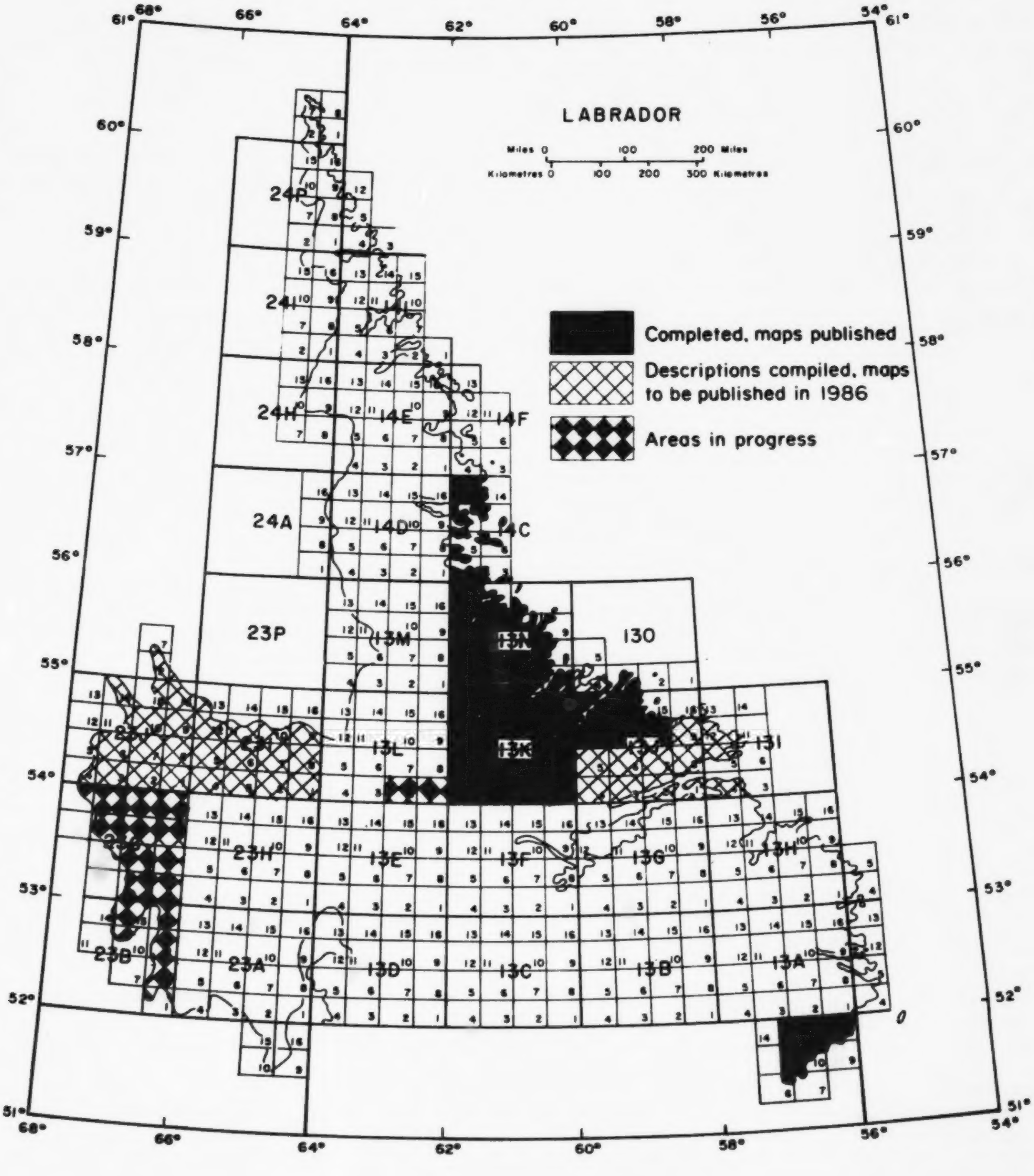
LABRADOR
Miles 0 100 200 Miles
Kilometres 0 100 200 300 Kilometres
Completed, maps published
Descriptions compiled, maps to be published in 1986
Areas in progress
68° 66° 64° 62° 60° 58° 56° 54°
61° 60° 59° 58° 57° 56° 55° 54° 53° 52° 51°
24P
24I
24H
14E
14F
24A
14D
14C
23P
13M
13N
13O
23I
23J
13L
13K
13J
13I
23H
13E
13F
13G
13H
23B
23A
13D
13C
13B
13A

Figure 2: *Index map for Mineral Occurrence Data System project, Labrador.*

COMPUTERIZED MINERAL INDEX

The computerized Mineral Index contains coded and free-format data, selectively extracted from the Mineral Inventory File. The purpose of the index is to efficiently organize important data on the occurrences so that a wide variety of retrievals can be made, taking advantage of the powerful sorting capabilities offered by computerization. The general categories of information that are considered appropriate for computerization are: identification, name and ownership, location, description of deposit, geological setting, exploration and development, and bibliography.

To manage the computer file and to help make retrievals, a computer program called GRASP (Geological Retrieval and Synopsis Program) has been installed on an AMDAHL 5860 computer at Newfoundland and Labrador Computer Services Limited. GRASP was developed at the United States Geological Survey (Bowen and Botbol, 1975) specifically as a geological data storage and retrieval system to be used primarily by geologists. It is a very easy system to use and highly interactive.

The file can be accessed through three high-speed terminals at the Department of Mines and Energy offices in St. John's. Presently, all of the island of Newfoundland and 13I, 13J, 13K, 13N, 13O and 14C in Labrador have been keypunched, edited and entered in the GRASP system.

USES OF MINERAL OCCURRENCE DATA SYSTEM

Prior to 1978, information on the geology, history of exploration, nature of mineralization and other important data on mineral properties could only be obtained by long research through numerous files. With the Mineral Occurrence Data System in place, preliminary research can now be done quickly and efficiently.

The system was built to serve four major-user communities. These are: 1) the exploration geologists and prospectors engaged in the search for mineral deposits in the province, 2) the geological staff of the Department of Mines and Energy engaged in mapping and evaluating the mineral potential of the province, 3) the Department of Energy, Mines and Resources which is building Canada-wide mineral occurrence files, such as the National Mineral Inventory, CANMINDEX and MINSYS, and 4) academic and research geologists and students of economic geology.

The manual Mineral Inventory File is used as a quick reference to specific deposits. Exploration company personnel frequently request descriptions of a particular mineral showing or prospect when they want a good summary or a list of references to carry out further research. This is particularly true when companies are new to the province or move into new areas. This preliminary research is generally done in our offices. However, since a large part of the file has been microfiched, it is available to all companies at a reasonable cost.

The Mineral Inventory File is used daily by government geologists in land-use planning. Advice is given to various departments of government in establishing wilderness areas, hydro developments, provincial and national parks, and any other developments which may conflict with future mineral exploration and development. In addition, municipal councils and the Department of Municipal Affairs are advised of the location, extent, and nature of mineral deposits in specific areas so that new housing and commercial developments, municipal parks, water reservoirs and sewage disposal systems can be located, where possible, in areas of low mineral potential.

Copies of the file are made available to the various agencies of the federal government such as the Mineral Policy Sector and the Geological Survey of Canada. These are then adapted to the National Mineral Inventory, MINSYS and CANMINDEX.

The file is available to anyone who is researching mineral deposits in the province. It is useful to students who are writing papers on specific mineral deposits as well as company and government personnel who are writing proposals for future work, or preparing information brochures about particular areas.

By the use of computers, the retrieval capability from the computerized Mineral Index is optimized and complex retrievals can be made which would be virtually impossible if a manual system were used.

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Current Research (1986) Newfoundland Department of Mines and Energy,
Mineral Development Division, Report 86-1, page 313

MINERAL ASSESSMENT REPORT LIBRARY - MICROFICHE PROJECT

N.L. Mercer
Publications and Information Section

The Mineral Development Division maintains a geological and mineral resource assessment file system which is referred to as the 'Mineral Assessment Report Library'. This library presently consists of approximately 9,000 geological and geochemical reports, maps, journal articles and mineral assessment files, making them the largest and most comprehensive single collection of geoscience documents about Newfoundland and Labrador.

As a result of the high level of mineral exploration activity experienced during the late 1970's and early 1980's throughout the province, the amount of new data submitted increased substantially. New information is now available on many of the old and numerous new mineral occurrences in the province. Much more is now known about the geology and mineral potential of various regions, both on the island and in Labrador.

The Mineral Development Division has also conducted a large number of field projects over the past few years. This has resulted in the publication of many new geological reports, maps and open files, as well as the results of numerous geochemical surveys and surficial and aggregate resource studies.

Mining and exploration companies, prospectors, geotechnical and consultant firms, government agencies, universities, libraries and the general public are continually making use of the geofiles; requests for information have increased substantially in the past few years.

During the past five years, the Publications and Information Section has been putting all of the good quality mineral assessment reports on microfiche. This provides a much more efficient system of maintaining the geofiles. Requests for information are processed more rapidly and easily, with relatively inexpensive charges for microfiche.

The microfiche project involves daily filming of batches of reports. The reports are cross-checked before filming for quality, content and reproducibility. Two microfiche originals are made and cataloged for each file. Filing follows the standard N.T.S. system. Duplicates can be copied from the original fiche upon demand. One set of fiche originals is stored offsite at the Torbay Core Library for security and protection from fire.

Microfiche sets of mineral assessment reports covering all 1:250,000 N.T.S. map sheets in insular Newfoundland are available along with microfiche sets for many of the Newfoundland General Series reports. Several releases have also been made for microfiche sets of mineral assessment reports covering all 1:250,000 N.T.S. sheets in Labrador except 23J and 23O.

Work on the Labrador mineral assessment reports is continuing and we are expecting to make several more releases of duplicate sets of microfiche by this spring. Labrador has been the focus of our attention this year and we are expecting to complete this phase of the project in 1986.

The total cost of mineral assessment reports which are available as microfiche duplicates is $1,950.00

During 1985, we also continued placing the mineral occurrence reports on microfiche and making them available. Presently, mineral occurrence reports for N.T.S. areas 2C, 2D, 2E, 2F, 2L, 2M, 11O, 12B, 12G, 12H, 12I, 12P, 13K, 13N, 14C are available. Further releases will be made as staff in the Mineral Deposits Section complete new N.T.S. areas.

For information, please contact Norman Mercer (709) 576-3159. We look forward to your comments and suggestions in improving our microfiche system.

ACKNOWLEDGEMENTS

Doreen Mahon is thanked for her excellent work on the microfiche project this past year.

The Department of Mines and Energy also acknowledges the continued participation and cooperation of Ches Hapgood and staff of the Micrographics Section, Newfoundland Department of Public Works and Services, especially in filming and duplicating the geofiles.

*Current Research (1986) Newfoundland Department of Mines and Energy,
Mineral Development Division, Report 86-1, page 314*

GEOSCAN - THE NATIONAL DATABASE FOR GEOLOGICAL INFORMATION: THE NEWFOUNDLAND CONTRIBUTION

Catherine Patey
Publications and Information Section

GEOSCAN is a computerized bibliographic database of Canadian-produced and/or Canada-related geoscience documents.

The Newfoundland Department of Mines and Energy is one of the ten agencies which index documents for input into this database. Our Mineral Assessment Report Library files and mineral inventory cards are the sources of our indexed documents. Other agencies, e.g. the Geological Survey of Canada and the Earth Physics Branch of the Canada Department of Energy, Mines and Resources, also produce and index documents that concern this province.

In 1982, the National GEOSCAN Center, which manages GEOSCAN, implemented a new software system, called MINISIS, to input and retrieve the bibliographic data more effectively. In the implementation of the new system, all the old documents were converted to a new format. For example, different types of keywords were moved into different fields: map types, illustrations, geological terms. Although most of the records did convert, they did not convert cleanly and completely. For example, reports may be missing a title or authors and terms may have been assigned to the wrong fields. In cooperation with the National GEOSCAN Center, these old documents are being corrected.

All new documents are input directly onto the new system and are immediately retrievable online. To date, only indexed documents from assessment files have been keyed into the system, although other types of documents, in particular government publications, have been coded.

Besides indexing and keying new documents, new coding sheets are being produced, the authority files or thesauri used in coding are being enlarged, and the terms used are being more clearly defined.

All of the 92,600 GEOSCAN records from across Canada, including those concerning this province, are available through online computer searches at the Geological Survey of Canada Library in Ottawa and, in St. John's, at our Publications and Information Section. Searches are performed on a cost-recovery basis with a minimal charge of $10.00 per search topic. A moderate size search (100-200 titles) costs between $15 and $45.

As well, GEOSCAN Newfoundland and Labrador indexes current to February 1982, the date of the last update on the old system, are available from the Publications and Information Section. A computer printout sorted by N.T.S. area is also available for the newer documents.

We welcome suggestions for improvements and appreciate being notified of any errors or discrepancies that you may discover in the earlier indexes. This will aid us in making detailed modifications of the documents.

For further information on GEOSCAN, please contact Catherine Patey (709) 576-3159.

Current Research (1986) Newfoundland Department of Mines and Energy,
Mineral Development Division, Report 86-1, page 315

REPORT OF THE GEOCHEMICAL LABORATORY FOR 1985

H.A. Wagenbauer
Geochemistry and Geophysics Section

Laboratory output for the past year is summarized in Table 1. The number of determinations decreased by 12 percent over the previous year, but all work on samples from the 1984 field season was completed prior to June 1, 1985. The decrease in output was due to a slightly lower demand for analytical work.

This respite allowed an inventory to be made of sample material remaining for the regional lake sediments and stream sediment samples collected over the past 12 years, and the commencement of some methods development.

During the past year the Mineral Laboratory acquired an ARL 3520 sequential quantometer from Applied Research Laboratories. The Mineral Laboratory is now in the process of setting up the instrument for the analysis of rare earths and other highly refractory elements which the laboratory was previously unable to provide to project geoscientists. A modern Graphite Furnace was added to our Atomic Absorption Equipment for the analysis of gold in the part per billion range. Considerable work has to be done before samples can be analyzed in a routine manner. It is hoped that the quantometer will be in operation by January 1986.

Table 1. Summary of the output from the geochemical laboratory of the Mineral Development Division from September 1, 1983 to August 31, 1984.

		Number of Determinations
Geochemical analyses of soil, till lake and stream sediments		48517
Silicate analyses		
Trace elements		24899
Major elements		12731
Miscellaneous analyses		
Assays, F, Ba, Sr, H_2O, CO_2 and S on a variety of sample types.		10254
	TOTAL	96401
		Number of Samples
Sample preparation		
Rock samples, hammer broken		107
Rock samples, crushed		3323
Rock samples, pulverized		3330
Lake, stream and soil samples sieved		2807
Miscellaneous		
Sample splitting, uranium weighing, samples shipped out for analysis		4320
Inventory of weights of lake and stream sediment samples on hand		40878

*Current Research (1986) Newfoundland Department of Mines and Energy,
Mineral Development Division, Report 86-1, page 316*

ACTIVITIES OF THE COMPUTER UNIT

Harjit Missan
Geochemistry and Geophysics Section

The Computer Unit was established in 1982 to provide data processing service to geologists involved in data analysis. The Computer Unit has a staff of three, viz., a manager, a system analyst and a programmer. Computer application needs of the Mineral Development Division are met by the use of the mainframe computer for large databases and the use of microcomputers for smaller datasets.

The mainframe computer used by the Division is the AMDAHL 5860 situated at Newfoundland and Labrador Computer Services Centre at Higgins Line. This computer is accessed through a cluster of three terminals and a printer connected via a permanent telephone line operating at 4800 baud. Some of the programs and their applications which are used by the staff of the Division are:

SPSS-X	for management of geochemical and geological data.
SAS	for management of geochemical and geological data.
GRASP	for management of mineral deposit data.
SIR	for management of surficial geology data.

In addition, plotting programs are used for display of spatial distribution of samples and the various chemical elements.

The Division's microcomputers are used by field geologists for data analysis and plotting of geochemical diagrams, e.g. X-Y plots and ternary diagrams. Since most of the geologists are not familiar with computer systems, the emphasis has been on the development of suitable programs that can be used by geologists without them having to become familiar or proficient in either computer systems or computer languages. Data are downloaded from the AMDAHL mainframe to the Tektronix 4054 Graphic System where geologists have been using MICRO-GRASP program for data analysis.

MICRO-GRASP is a program designed for the storage, transformation, and selection of data in tabular form. The user controls the execution of MICRO-GRASP by entering a series of 'commands'. These commands allow users to enter new data records, establish selection criteria, calculate summary statistics, display selected data values, and perform arithmetic operations. In addition, the user can do graphics work such as plotting X-Y and ternary diagrams. These can either be drawn on the screen or output to a high resolution plotter which can produce camera ready plots.

A portable microcomputer (Compaq Portable) was used in the field this year by a departmental geophysicist; the microcomputer was used to record, store and reduce magnetic data. Once entered, the field data was manipulated to give a hard copy output either as listings or profiles. The microcomputer was used to carry out the necessary calculations and corrections to reduce the raw field data to their final format, examples of this being magnetic corrections.

In addition to providing support and help to end users, the unit will be involved in developing systems which will allow the integration of data from various disciplines within the geosciences for the purpose of highlighting areas of potential mineralization. The Division will be involved in a pilot project called Characteristic Analysis, which is a multi-variate statistical procedure developed specifically for integrating regionalized multi-variate data in geology, geochemistry, geophysics and remote sensing. This will allow a quantified analysis of the favourability of mineralized areas to contain deposits of a certain type.

ICE FLOW TRENDS AND DRIFT COMPOSITION, FLOWERS RIVER AREA, LABRADOR[1]

Project 820039

R.A. Klassen and A.M. Bolduc
Terrain Sciences Division

Klassen, R.A. and Bolduc, A.M., Ice flow trends and drift composition, Flowers River area, Labrador; in Current Research, Part A, Geological Survey of Canada, Paper 86-1A, p. 697-702, 1986.

Abstract

Regional ice flow trends, representing the last phase of flow in the Flowers River area of central Labrador, vary from N55°E in the southeast to N85°E in the north. Farther west, the trends are generally eastward and, near major river valleys, appear topographically controlled. Evidence of an older, more northward phase (or phases) of flow (N10°E to N45°E) was found at several locations. Far travelled (>50 km) erratics of red sandstone occur throughout the area; although their specific bedrock source is not known, they appear derived from the Siamarnekh Formation, or unmapped outliers of it. Local scale (1 to 10 km) dispersal trains originating from a volcanic pile are defined by fine grained, porphyritic rock and by till geochemistry. Geochemically 'anomalous' till samples of unknown origin, defined by trace elements and rare earth elements, occur over the peralkaline granite batholith of the Flowers River Igneous Suite.

Résumé

Les directions régionales d'écoulement des glaces de la dernière phase d'écoulement dans le secteur de la rivière Flowers, dans le centre du Labrador, vont de N55°E au sud-est à N85°E au nord. Plus loin à l'ouest, les directions sont généralement est et, à proximité des grandes vallées fluviales, elles semblent être contrôlées par la topographie. On a trouvé, à plusieurs endroits, des indices d'une ou de plusieurs anciennes phases d'écoulement plus vers le nord (N10°E à N45°E). On trouve dans tout le secteur des blocs erratiques de grès rouge qui ont parcouru de longues distances (>50 km); bien que l'origine de ces blocs ne soit pas connue, ils semblent appartenir à la formation de Siamarnekh ou aux avant-buttes non cartographiées de cette dernière. Des trainées de dispersion restreinte (1 à 10 km) provenant d'un amas de roches volcaniques sont constituées de roches porphyriques à grains fins et sont apparentées à la géochimie des tills. Des échantillons de tills de géochimie "anomale", d'origine inconnue et caractérisés par des éléments à l'état de trace et des éléments de terres-rares recouvrent le batholite granitique et peralcalin de la série endogène de Flowers River.

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[1] Contribution to Canada-Newfoundland Mineral Development Agreement 1984-89. Project carried by Geological Survey of Canada.

ICE FLOW DIRECTIONS AND DRIFT COMPOSITION, CENTRAL LABRADOR[1]

Project 820039

F.J. Thompson and R.A. Klassen
Terrain Sciences Division

Thompson, F.J. and Klassen, R.A., Ice flow directions and drift composition, central Labrador; in Current Research, Part A, Geological Survey of Canada, Paper 86-1A, p. 713-717, 1986.

Abstract

Glacial striae over much of the study area are oriented east-northeast. Evidence from older striae indicates that a major northeast directed ice advance, which affected the entire study area, predates the east-northeast advance. Northeast oriented striae in the northeast part of the study area are attributed to this early advance. Striae trending east-southeast in the southern part of the area may reflect divergent flow during the east-northeast advance or a separate phase of flow. The distribution of glacial erratics shows broad fan-shaped eastward dispersal of 30 to more than 100 km from their bedrock sources. The transport of erratics and development of fan shapes are related to the multiple phases of flow recorded by striae. The complex history of glacial transport and difficulties in sampling till highlight the importance of scientific input for effective use of glacial debris as a prospecting medium in central Labrador.

Résumé

Des stries glaciaires recouvrant la majeure partie de la région d'étude sont orientées est-nord-est. Des anciennes stries indiquent qu'une important avancée glaciaire de direction nord-est, qui a modifié toute la région, a eu lieu avant l'avancée est-nord-est. Les stries nord-est dans la partie nord-est de la région sont attribuées à cette première avancée. Les stries est-sud-est dans la partie sud peuvent être le résultat d'un écoulement divergent pendant l'avancée est-nord-est ou d'une phase distincte d'écoulement. La répartition des blocs erratiques d'origine glaciaire indique une importante dispersion en éventail vers l'est, sur 30 à plus de 100 km à partir de leurs sources dans la roche en place. Le transport des blocs erratiques et leur dispersion en éventail sont associés aux phases multiples d'écoulement indiquées par les stries. L'histoire complexe du transport glaciaire et les difficultés dans l'échantillonnage des tills font ressortir le besoin de données scientifiques pour une utilisation efficace des débris glaciaires comme moyen de prospection dans le centre du Labrador.

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[1] Contribution to Canada-Newfoundland Mineral Development Agreement 1984-89. Project carried by Geological Survey of Canada.

STRUCTURAL AND MAGMATIC CONTROLS ON THE INTERNAL GEOMETRY OF THE PLUTONIC COMPLEX AND ITS CHROMITE OCCURRENCES IN THE BAY OF ISLANDS OPHIOLITE, NEWFOUNDLAND[1]

Contract 27ST.23233-5-0247

S. Dunsworth[2], T. Calon[2], and J. Malpas[2]

Dunsworth, S., Calon, T., and Malpas, J., Structural and magmatic controls on the internal geometry of the plutonic complex and its chromite occurrences in the Bay of Islands Ophiolite, Newfoundland; in Current Research, Part A, Geological Survey of Canada, Paper 86-1B, p. 471-482, 1986.

Abstract

Detailed mapping in the Springers Hill area of the Lewis Hills Massif illustrates a complex history of synkinematic multiple intrusion and ductile deformation for the Bay of Islands Ophiolite Complex. The plutonic sequence is divided into an earlier deformed ophiolite and later synkinematic, heterogeneously deformed, ultramafic to gabbroic plutons which intrude the earlier sequence. Structural overprinting of the regional mantle tectonite fabric (S_1) by a broad, high temperature shear zone with an $L_2 \geq S_2$ mylonitic fabric is documented. Three unique types of chromite concentrations in the Springers Hill, Stowbridge and Bluff Head areas are recognized on the basis of their petrological setting and structural controls.

A simple, single, steady-state magma chamber model is inadequate to explain the evolution of the Bay of Islands plutonic complex. Our data show a complicated history of high temperature deformation and syn- to post-kinematic multiple intrusion which progressively modified the original geometry of the plutonic sequence and its chromitiferous bodies.

Résumé

Les cartes de détails établies dans la région de Springers Hill où se situe le massif Lewis Hills montrent que le complexe ophiolitique de Bay of Islands a connu une évolution compliquée, faite de multiples intrusions syntectoniques et de déformation ductiles. La séquence plutonique comprend une sous-séquence ophiolitique déformée et une sous-séquence postérieure constituée de plutons ultramafiques à gabbroiques syntectoniques, déformées de façon hétérogène, qui fait intrusion dans la première. Les auteurs montrent comment une vaste zone de cisaillement à haute température de texture (S_1) molynotique $L_2 \geq S_2$ s'est superposée à la structure tectonitique du manteau régional. On distingue trois types de concentrations de chromite dans les régions de Springers Hill, de Stowbridge et de Bluff Head, d'après des facteurs pétrologiques et structuraux.

L'évolution du complexe plutonique de Bay of Island ne saurait s'expliquer uniquement par un simple modèle de chambre magmatique à l'état stable. Les données recueillies par les auteurs mettent plutôt en évidence une série compliquée de déformations à haute température et de multiples intrusions syntectoniques et post-tectoniques qui ont peu à peu modifié la géochimie originale de la séquence plutonique et de ses massifs chromitifères.

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[1] Contribution to the Canada-Newfoundland Mineral Development Agreement 1984-89. Project carried by Geological Survey of Canada, Economic Geology and Mineralogy Division, Project 770063.

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GEOLOGY OF THE SILVER MOUNTAIN AREA, WESTERN NEWFOUNDLAND[1]

J.V. Owen[1]
Precambrian Geology Division

Owen, J.V., Geology of the Silver Mountain area, western Newfoundland; in Current Research, Part A, Geological Survey of Canada, Paper 86-1A, p. 515-522, 1986.

Abstract

The geology of the Silver Mountain area of the northern Long Range Mountains of western Newfoundland is dominated by crystalline Precambrian rocks which record an extended history of metamorphism, deformation and intrusion. The oldest rocks are granulite-facies quartzofeldspathic gneisses of inferred igneous parentage, and include (quartz) dioritic to granitic variants, and spatially associated anatectic(?) biotite granite. Biotite ± garnet ± sillimanite ± spinel ± graphite-bearing migmatitic gneisses, of uncertain age relative to the orthogneiss, are associated with quartzite and metacarbonate bands, and are inferred to be paragneisses. The gneissic rocks are intruded by a large pluton of mafic rocks, including mesocratic to leucocratic, pyroxene ±olivine ± amphibole-bearing metagabbro, and pegmatitic metagabbro, and by a variety of massive to foliated granites and granodiorites. Quartz-rich mica schist with quartzite interbands, banded marble, massive to foliated felsic porphyry, and mafic schist occurring in the southwestern portion of the map area are considered to be lower Paleozoic (Cambro-Ordovician?). The schistose rocks have been thrust westward over the Precambrian gneisses and intrusive rocks, and are partly overlain by undeformed conglomerates and redbeds of the Deer Lake basin.

Résumé

La géologie de la région du Mont Silver dans la partie nord des monts Long Range, dans l'ouest de Terre-Neuve, présente surtout des roches cristallines précambriennes dont les antécédents de métamorphisme, de déformation et d'intrusion remontent à un passé très lointain. Les plus anciennes de ces roches sont des gneiss quartzofeldspathiques d'origine présumémant ignée, appartenant au faciès des granulites et comprenant des variantes dioritiques (quartziques) à granitiques; un granite anatectique(?) à biotite y est géographiquement associé. Des gneiss migmatiques à biotite ± grenat ± sillimanite ± spinelle ± graphite, dont l'âge est incertain par rapport à l'orthogneiss, sont associés à des intercalations de quartzite et de métacarbonates et laissent supposer qu'il s'agit de paragneiss. Les roches gneissiques ont été traversées par un vaste pluton de roches mafiques, notamment un métagabbro mésocrate ou leucocrate à pyroxène ± olivine ± amphibole et un métagabbro pegmatitique, et par une gamme de granites et de granodiorites massifs ou feuilletés. Du schiste à mica riche en quartz contenant des intercalations de quartzite, un marbre rubané, un porphyre felsique massif ou feuilleté et un shiste mafique trouvé dans la partie sud-ouest de la région cartographique dateraient du Paléozoïque inférieur (cambro-ordovicien?). Ces roches schisteuses ont été déplacées vers l'ouest pour chevaucher les gneiss et les roches intrusives précambriennes et sont partiellement recouvertes par des conglomérats et des couches rouges non déformées du bassin de Deer Lake.

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[1] Contribution to the Canada-Newfoundland Mineral Development Agreement 1984-1989. Project carried by Geological Survey of Canada, Project 850017

ASSESSMENT OF LEAD-ZINC DEPOSITS OF THE WESTERN NEWFOUNDLAND CARBONATE PLATFORM[1]

Contract 34SZ. 23233-5-0350

Cynthia M. Saunders[2] and D.F. Strong[2]

Saunders, C.M. and Strong, D.F., Assessment of lead-zinc deposits of the western Newfoundland carbonate platform; in Current Research, Part A, Geological Survey of Canada, Paper 86-1A, p. 229-237, 1986.

Abstract

Sixty-one mineral occurrences in the carbonate platform of western Newfoundland were examined and sampled. The occurrences are found in Cambrian to Mississippian limestones and dolostones which outcrop from Port au Port to the tip of the Great Northern Peninsula. The occurrences can be grouped into two broad types. Type I is sphalerite ± galena mineralization associated with white dolomite spar gangue – "Mississippi Valley type". The amount of sulphides and gangue is a function of the secondary porosity of the rocks which decreases with their age. Type II mineralization is vein/open-space filling associated with calcite and barite gangue and is dominantly of Mississippian age. The mineralization is confined to veins in less permeable Cambrian and Ordovician strata and tends to fill open spaces in more permeable Mississippian rocks.

Résumé

Soixante et une venues minérales ont été étudiées et échantillonnées dans la plate-forme de roches carbonatées, de l'ouest de Terre-Neuve. Ces venues se trouvent dans des calcaires et des dolomies d'âge cambrien à mississippien et affleurent de Port-au-Port jusqu'à la pointe de la péninsule Great Northern. Ces venues peuvent être regroupées en deux grands types. La minéralisation du type I est constituée de sphalérite ± galène dans une gangue de cristaux blancs de dolomite; il s'agit du type <<Mississippi Valley>>. Les proportions de sulfures et de gangue sont fonction de la porosité secondaire des roches qui décroît avec l'âge de ces dernières. La minéralisation du type II renferme des matériaux de remplissage de filons et d'espaces libres dans une gangue de calcite et de barytine; elle est principalement d'âge mississippien. La minéralisation est restreinte aux filons se trouvant dans des couches moins perméables du Cambrien et de l'Ordovicien et a tendance à remplir les espaces libres dans les roches plus perméables du Mississippien.

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[1] Contribution to the Canada-Newfoundland Mineral Development Agreement 1984-89. Project carried by Geological Survey of Canada, Economic Geology and Mineralogy Division, Project 650056.

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GEOLOGICAL SETTING OF SULPHIDE MINERALIZATION AT TILT COVE, NEWFOUNDLAND[1]

Contract DSSOSZ85-00010

D.F. Strong[2] and C.M. Saunders[2]

Strong, D.F. and Saunders, C.M., Geological setting of sulphide mineralization at Tilt Cove, Newfoundland; in Current Research, Part A, Geological Survey of Canada, Paper 86-1A, p. 319-325, 1986.

Abstract

Three main stratigraphic units are recognized in the Tilt Cove area; the Betts Cove ophiolite and the Bobby Cove Formation of the Snooks Arm Group, both Lower Ordovician, and the Silurian Cape St. John Group. Massive sulphide mineralization occurs in the ophiolite pillow lava unit close to its base, as at Betts Cove. The Cape St. John Group unconformably overlies the ophiolite, but is also tectonically interleaved with it. Magnetite-bearing cherts are associated with both the basalt and sandstones at the base of the Cape St. John Group, and locally contain Au as well as Cu mineralization. Metasomatic gain or loss of silica has produced a silica-rich and a silica-poor group from the relatively less altered pillow lavas, which exhibit chemical variation related to advanced partial melting of the upper mantle.

Résumé

Trois principales unités stratigraphiques se trouvent dans la région immédiate de Tilt Cove: l'ophiolite de Betts Cove et la formation de Bobby Cove, les deux appartenant au groupe de Snooks Arm et datant de l'Ordovicien inférieur, et le groupe silurien de Cape St. John. Des minéralisations de sulfures massifs sont localisées dans les laves en coussins près de la base de cette unité, comme à Betts Cove. Le groupe de Cape St. John repose en discordance sur l'ophiolite, mais est également tectoniquement interstratifié avec ce dernier. Des cherts renfermant de la magnétite sont associés aux basaltes et grès à la base du groupe de Cape St. John, et contiennent par endroits des minéralisations en Au et Cu. Des gains et pertes métasomatiques de silice ont produit des roches enrichies et appauvries en silice à partir des laves en coussins moins alterées qui, elles-mêmes, témoignent de changements chimiques liés à la fusion avancée du manteau supérieur.

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[1] Contribution to the Canada-Newfoundland Mineral Development Agreement 1984-89. Project partly carried by Geological Survey of Canada, Economic Geology and Mineralogy Division, Project 840059.

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STRATIGRAPHY AND ECONOMIC GEOLOGY OF THE SOUTHERN PART OF THE ROBERTS ARM GROUP, CENTRAL NEWFOUNDLAND[1]

Project 840059

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Economic Geology and Mineralogy Division

Swinden, H.S. and Sacks, P.E., Stratigraphy and economic geology of the southern part of the Roberts Arm Group, central Newfoundland; in Current Research, Part A, Geological Survey of Canada, Paper 86-1A, p. 213-220, 1986.

Abstract

The Roberts Arm Group is a sequence of Ordovician marine volcanic, subvolcanic, and volcaniclastic rocks, in fault contact to the east with strongly deformed metasedimentary rocks and intruded by Acadian granitoid rocks. In the west the group is cut by outliers of the Topsails Intrusive Suite.

Five west facing lithostratigraphic units have been traced from Great Gull Pond south to Lake Bond, informally designated from east to west Baker Brook Basalt, Gull Hill sediments, Burnt Island Basalt, Gullbridge felsic volcanics, South Brook basalt. These units are tentatively correlated with similar stratigraphic units in the Handcamp area.

Volcanogenic mineralization occurs mainly in the Burnt Island basalt and Gullbridge volcanics. The polymetallic Handcamp prospect contains significant amounts of precious metals, hosted in a unit interpreted as equivalent to the Gullbridge felsic volcanics. Exhalative products of the alteration systems have not been identified; however exhalative sulphides if present, may occur only above the highest recognized alteration in the South Brook basalt.

Résumé

Le groupe de Roberts Arm, une séquence de roches volcaniques, volcanoclastiques et sous volcaniques de nature marine et d'âge ordovicien, est en contact de faille, à l'est, avec des roches métasédimentaires fortement déformées et pénétrées par des roches granitoïdes d'âge acadien. À l'ouest, le groupe est pénétré par des avant-buttes de la suite intrusive de Topsails.

Cinq séquences lithostratigraphiques orienteés vers l'ouest ont été suivies vers le sud, de l'étang Great Gull jusqu'au lac Bond. Celles-ci sont officieusement designées, de l'ouest à l'est, le basalte de Baker Brook, les sédiments de Gull Hill, le basalte de Burnt Island, les roches volcaniques felsiques de Gullbridge, et le basalte de South Brook. Ces unités sont provisoirement corrélées avec une séquence stratigraphique similaire dans la région de Handcamp.

Des minéralisations volcanogènes se manifestent surtout dans le basalte de Burnt Island et les roches volcaniques de Gullbridge. Le dépot polymétallique de Handcamp, qui contient des concentrations importantes de métaux précieux, se trouve dans une unité stratigraphiquement équivalente aux roches volcaniques felsiques de Gullbridge. Les produits exhalatifs associés aux systèmes d'altération n'ont pas été identifiés, mais peuvent exister, le cas échéant, au dessus de l'altération stratigraphiquement la plus haute reconnue à date dans le basalte de South Brook.

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[1] Contribution to the Canada-Newfoundland Mineral Development Agreement 1984-1989. Project carried by Geological Survey of Canada.

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THE GREAT BEND OPHIOLITE, EASTERN NEWFOUNDLAND: FIELD INVESTIGATIONS[1]

Contract 58SZ.23233-5-0246

Edward J. Zwicker and D. F. Strong[2]

Zwicker, E.J. and Strong, D.F., The Great Bend ophiolite, eastern Newfoundland: field investigations; in Current Research, Part A, Geological Survey of Canada, Paper 86-1A, p. 393-397, 1986.

Abstract

Geological mapping of the ultramafic and gabbroic rocks of the Great Bend area, at 1:5000 scale, has substantially revised previous interpretations. In particular, a belt of sedimentary rocks has been found to separate the gabbroic from the ultramafic rocks, which allows for the possibility that the two suites of igneous rocks may have separate emplacement histories and even separate origins. The area contains several types of mineralization of economic interest. The mapping has significantly increased the extent of the known talc-magnesite zones, but substantiates the suggestion of earlier workers that the mineralization is controlled by fault and shear zones. Chromite lenses and pods are common throughout the serpentinized harzburgites and dunites. Pyrite and arsenopyrite are associated with quartz veins and also occur as disseminated zones in sedimentary rocks surrounding the ophiolite, and these have some gold potential.

Résumé

La cartographie géologique à 1/5 000 des roches ultramafiques et gabbroïques de la région de Great Bend a commandé une revision de certaines interprétations antérieures. En particulier, on a observé qu'une zone de roches sédimentaires sépare les roches gabbroïques des ultramafiques, d'où des époques différentes et à partir de sources différentes. La région renferme plusieurs types de minéralisation qui présentent un intérêt économique. Par suite de ces travaux, on a considérablement augmenté l'étendue des zones connues de talc-magnésite, mais on conclue, comme l'ont fait d'autres auteurs antérieurement, que la minéralisation se trouve sous l'influence de zones de failles et de cisaillement. Les dunites et harzburgites serpentinisées abondent en lentilles et en "pods" de chromite. La pyrite et l'arsénopyrite sont associées à des veines de quartz, et on en trouve également sous forme de zones disséminées dans des roches sédimentaires qui entourent l'ophiolite, où elles ont un certain potentiel aurifère.

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[1] Contribution to the Canada-Newfoundland Mineral Development Agreement 1984-1989. Project carried by Geological Survey of Canada, Economic Geology and Mineralogy Division, Project 770063.

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NOTES

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